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DEFENSE PRODUCTS DIVISION
Fairchild Camera and Instrument Corporation
Robbins Lane, Syosset, New York

# HIGH ACUITY RECONNAISSANCE

SME-CA-81B
2 March 1959

Copy No. 4

DEFENSE PRODUCTS DIVISION
Fairchild Camera and Instrument Corporation

Proposal No. SME-CA-81B
2 March 1959

## ABSTRACT

Presentation of a maximum information content reconnaissance system for use at an altitude of [redacted] and a vehicle velocity of Mach 4.

The system works in both the visual and far infra-red portions of the electromegnetic spectrum. The system is limited only by the vehicle characteristics, space and weight considerations. Use is made of the most advanced techniques and designs. Recommendations are made for a complete system including the primary camera, auxiliary cameras, infra-red sensor, and ground support equipment.

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# SECTION I

## INTRODUCTION

This proposal presents design data and recommendations for a photo reconnaissance system for a manned aircraft to operate at an altitude of [redacted] and velocity of Mach 4. The data presented describes a system which will give the maximum information content compatible with the space and weight limitations of the vehicle. The philosophical approach has been directed toward a system which will satisfy the three basic reconnaissance questions:

1. Is there anything there?
2. What is it?
3. Where is it?

and toward a system which follows good reconnaissance practice, is reliable, and which will take advantage of all the latest developments in the state of the art.

This proposal follows and supersedes the preliminary technical notes submitted by Fairchild in Reports No. SME-CA-81 and SME-CA-81A, dated 1 February 1959 and 18 February 1959, respectively.





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The system presented is the result of much detailed study on both camera design potentials and possible application to the vehicle configuration.

The basic system comprising a primary camera and secondary camera is described and discussed in detail in the following sections.

As a possible adjunct for augmentation of information, the inclusion of an infra-red reconnaissance sensor is presented and discussed briefly in the final section.

# SECTION II

## BASIC DESIGN CONFIGURATION

The two major requirements of this system, maximum information capacity and maximum reliability, Fairchild is of the opinion will be best satisfied by providing a dual photographic capability. In Figure 1 is shown a simplified sketch of how this may be attained within the space limitations imposed by present thinking with regard to the vehicle design. To the right in this figure is seen a high acuity long focal length, panoramic camera of the chimney type; while to the left, a short focal length dual mapping camera. While Fairchild feels this combination is to be preferred, alternative arrangements are also presented which may be more desirable when the primary sensor in the system is other than photographic in nature.

### Primary Camera

That the high acuity element should be a panoramic camera is reasonably obvious when one considers the angular field of coverage that is required. Any attempt to utilize a conventional single frame camera to achieve the same level of performance would require lens characteristics which the optical art cannot provide. The panoramic approach overcomes this difficulty by effectively operating only in

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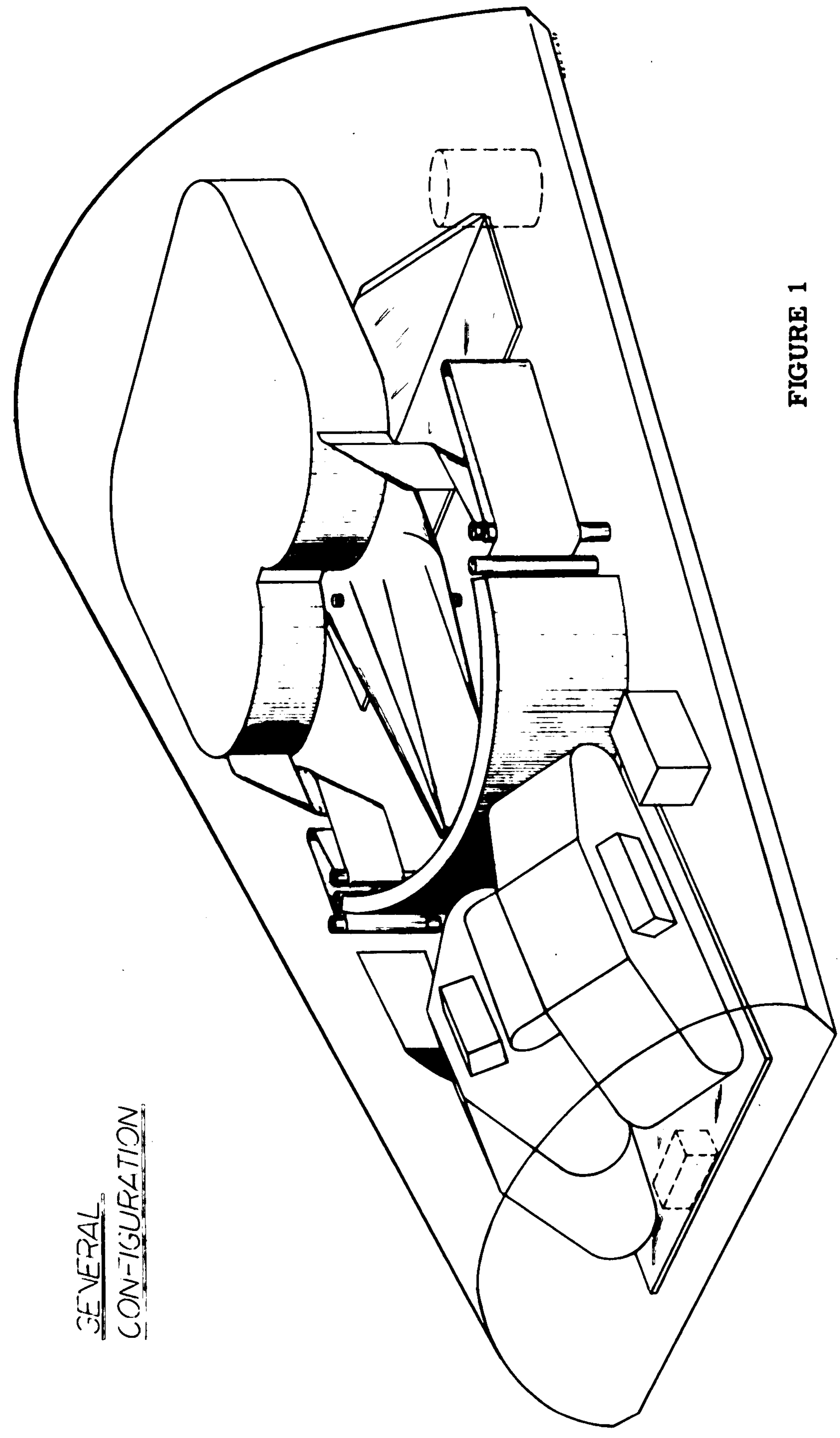



FIGURE 1

the vicinity of the optical axis of the lens where superlative imagery can be attained. Of the many types of panoramic systems which have been devised, the chimney type will inherently permit the highest degree of photographic acuity. The most significant reason for this lies in the fact that there is no synchronizing requirement between lens and film motions during scan other than that required for forward movement compensation. As the lens rotates about its nodal point, the image is stationary and there is no image motion relative to the stationary film located in the focal plane arc. In all other types of scanning panoramic cameras, there is a synchronized motion required either between certain optical elements or between the image motion and the film motion. The chimney type panoramic proposed is quite similar to that of a current development by Fairchild. The film handling reliability is extremely high and many of the detailed problems relative to performance capability have been worked out. For the above reasons, together with wide associated experience in this field, Fairchild considers maximum information capacity over large angular fields can be attained only with a chimney type panoramic. A camera of this type with a lens made to the Baker high acuity design, currently being built for Fairchild as part of the Air Force High Acuity Camera System, offers the maximum potential in intelligence gathering capacity.

Secondary Camera

In conjunction with the panoramic unit, it is proposed to include a dual mapping camera arrangement in a split vertical installation. The purpose of this part of the system is to provide information for accurate topographic analysis which cannot easily be obtained from a panoramic view considering that the system platform can never be perfectly stable. As all elements in the field of a panoramic camera are not exposed simultaneously, there will be of necessity some angular shift of the selected control points which will be generally an unknown function of the position of the control points in the field. In a single frame camera, such motion will affect all points equally. As a result, the inclusion of the supplementary mapping camera is essential to insure maximum accuracy in the precise location of ground points. In addition, of course, this part of the system will provide a certain amount of redundancy in information which is desirable from the standpoint of reliability. The statements made previously, with regard to the use of a single frame camera to obtain high level of performance over a wide angle, still apply. As a result, it is felt that the use of two such cameras, each covering half the angular field, is the best compromise with due regard to space limitations imposed by the vehicle. This dual arrangement will permit accurate wide

angle coverage mapping capability utilizing existing ground support equipment for photogrammetric analysis.

Alternate Secondary Cameras

While Fairchild feels that for cartographic and geodetic reasons the supplementary camera system should take the form of a dual mapping camera, it is recognized that for installations in which the primary sensor is not the 18-inch high acuity panoramic, higher information capacity may be desired of this secondary camera than is possible with the dual mapping cameras. Consequently, there is illustrated in Figure 2A, a configuration employing a 6-inch focal length chimney type panoramic camera, in place of the dual mapping unit. This camera will utilize 70MM film and scan through an angle of 110° with film capacity sufficient for complete photographic coverage of the mission. The lens will be of the same degree of optical excellence as that in the primary 18-inch sensor and will provide the same information gathering capacity, except as limited by the shorter focal length. In Figure 2B is shown a further alternative arrangement employing a 12-inch auxillary chimney type panoramic for installations in which the volume occupied by the primary sensor permits. This camera will use 70MM thin base film

and cover a scan angle of 90°. The performance of this unit will be similar to the 6 inch discussed above with the exception of increased acuity resulting from the longer focal length.

Camera Coverage

The proposed camera system provides a capability of stereoscopic photographic coverage in a single mission of about 146,000 square miles with the primary camera, about 186,000 square miles with the alternate 6" panoramic, about 134,000 square miles with the 12" panoramic and about 305,000 square miles with the dual mapping camera installation. Since no specific mission or flight plan is considered, these values are given for a continuously operating unit in a condition of straight and level flight.

The coverage of a single exposure made by each of the cameras is shown in Figure 3 with ground distances indicated in statute miles.

General Design Discussion

Additional details of the preferred photographic subsystem of Figure 1 are shown in Figure 2. Because of the compartment space and size, it has been found necessary in this configuration to make certain compromises. For example, an initial attempt was made to provide a 24 inch focal length chimney type panoramic

camera using the Baker 24 inch f4.0 Apochromat High Acuity Lens. This lens is fully developed and in the final phases of fabrication. It was determined, however, that even with 5 inch thin base film, the compartment could not permit installation of 26 inch diameter spools required for the total operating time of one hour and forty minutes. It should be pointed out that, while the acuity of the system may be slightly decreased with the shorter focal length, there are some concommitant advantages. The most important of these is that, with the same percentage overlap of successive frames, the photographic base line is larger thus enabling more accurate determination of heights by stereo techniques.

After some disucssion with Dr. Baker with respect to his lens, it was decided that an 18 inch focal length chimney type panoramic camera was the best compromise. The proposed camera, therefore, incorporates a scaled down version of the 24 inch f4.0 Baker lens and provides the same high acuity characteristics as presently exist. This is true because the coverage capability of the 24 inch lens is the diagonal of a 4-1/2" by 4-1/2" format whereas the requirement for the 18 inch lens will be an approximate 4-1/2" slit length. Hence, the configuration shows an 18 inch focal length chimney type panoramic camera with 90° total field

coverage on 5 inch thin base film. This camera is installed in a horizontal position in the compartment with a fixed 45° mirror in front of the lens. Again, because of space limitations, the film spools cannot be oriented in the same plane as the focal plane arc of the camera. However, recent experience with film handling in a similar application utilizing skewed rollers to provide necessary film plane transition has been highly successful. Another reliable way of changing film plane direction is to provide loose loop transition by metering the film, with a loop sensor, at both ends of the loop.

It can be seen from the configuration that the supply and take-up spools use the space-sharing technique in order to provide the required capacity for the entire operating time specified. This technique also has been successfully implemented by Fairchild on previous panoramica camera development programs. It is possible to avoid the space sharing if the spool axes are rotated to arbitrary angles compatible with the configuration. This as well as other possibilities would be investigated during the initial phase of the program and discussion with the vehicle designers.

Forward Motion Compensation for a chimney type panoramic camera can be readily accomplished by moving the lens perpendicular

to the scan direction. A follower on the lens, at some radius from the nodal point of rotation, drives the lens in conjunction with a fixed flat plate tilted at the appropriate angle. For variations in forward motion compensation the scan rate can be proportionate, thereby permitting forward motion compensation in its simplest and most accurate form. To cope with any yaw compensation, the flat plate need only be rotated through the required angle in conjunction with the 45° mirror. This will provide theoretically perfect forward motion compensation for the yaw angle and cause only a slight amount of unbalanced ground coverage from the ground track nadir line.

Illustrative of the need for analyzing proposed configuration in intimate detail, one can consider the question of how the film should be positioned in the oscillating lens, stationary film panoramic camera. The film may either be located on a cylindrical surface concentric with the axis of rotation, or may be positioned by locating rollers so as to be normal to the lens axis during exposure. If the exposing slit were infinitely narrow, there would be no difference in these two arrangements. However, as the slit must have finite width and the camera lens is designed with a flat focal plane because of the practical difficulty of warping film to fit a spherical surface, the pros and cons of each must be considered. In the

cylindrical film approach, there is no image motion but the image does not remain in exact focus during exposure. In the second, the image remains in focus but there exists some relative motion between lens and image during exposure. Analysis of the two configurations shows that the out-of-focus effect of the first varies as the square of angular width of the slit while the relative motion in the second varies as the cube of this angle. Since the angular width of the slit is small, it is found that there is approximately 4 times more potential image degradation in the cylindrical film approach than in the flat film arrangement. It should be pointed out that the acutal amount of degradation is so small for either case as to be insignificant except for high acuity systems.

The dual mapping camera system will use the Baker 3" focal length lens on a 4-1/2" by 4-1/2" format with synchronized between-the-lens type shutters, the synchronization of exposure being a basic requirement of modern photogrammetric analysis to be made on the resulting pictures. Because of the basic mission required of these cameras and their relatively short focal length, these cameras will not be provided with forward motion compensation. The same 5" thin base film that is used in the main camera system will also be used. Fairchild has developed dual mapping cameras recently that

have proven to be excellent for mapping and charting purposes. Since the configuration is limited in space, use of this dual camera arrangement is an excellent solution which provides wide angular coverage with no compromise of conventional mapping techniques.

The performance of the proposed basic system under optimum atmospheric conditions using Eastman SO-1213 (or equivalent) emulsion on a thin base will be 2 foot ground resolution for the panoramic camera and 20 seconds angular accuracy for the mapping component.

Rejected Configurations

During preliminary consideration of other possible approaches particular attention was given to panoramic systems utilizing a double-dove prism. It was determined that, aside from severe synchronization problems, this type of camera would necessitate an impossibly close control of the ambient temperature in order to deliver high acuity performance. Assuming an 18" f/4 lens, the acutal glass path through which the light must travel in a double-dove scanning prism will be approximately seven inches, if the aperture is not restricted. Consider the case where the camera is looking straight down and both halves of the prism are being used equally. If a temperature difference exists between the two

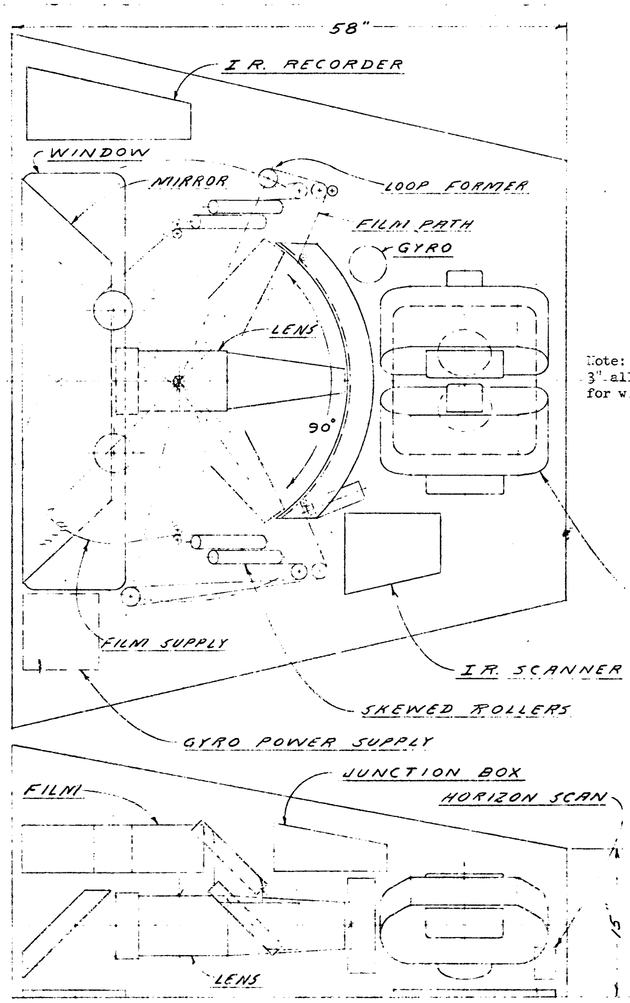
halves, the original wave front will be divided into two parts between which there will be a phase difference caused by the difference in optical path. For this to be negligible, the Rayleigh criterion states that the difference should be less than one-quarter wave,

$$\text{Optical path difference} = 7\Delta n = \frac{\lambda}{4}$$

$$\text{or} \qquad \Delta n \approx 10^{-6}$$

where $\Delta n$ is the change in index caused by temperature. A reasonable value for the coefficient of index of refraction change with temperature is $10^{-5}$ per degree C, with the result that the temperature of the two halves should not vary by more than 0.1°C. To maintain the temperature of the prism to such a degree would appear to be a practical impossibility. As a result, the double-dove configuration was dropped from further consideration.

Other types of panoramic cameras, such as nodding lens, nodding mirror and traveling lens with mirror or prism were investigated to determine if there were system advantages. These types were dropped, however, primarily due to lower dynamic information content resulting from practical limitations or synchronization.




| UNIT | WEIGHT |
|---|---|
| Panoramic Camera (Incl. mirror) | 80 |
| Film (Panoramic Camera) | 63 |
| Dual Mapping Camera 30# each x 2 | 60 |
| Film (Dual Mapping Camera) 5# each x 2 | 10 |
| Junction Box | 8 |
| Timer (Crystal Oscillator) | 2 |
| IR Scanner and Recorder | 60 |
| Misc. (Wiring etc.) | 10 |
| Sub Total | 293 lbs. |
| Gyro | 6 |
| Gyro Power Supply | 15 |
| Horizontal Scan System | 4 |
| | ---- |
| Total | 318 lbs. |

Note: Approximately 3" allowed all around for wall thickness.

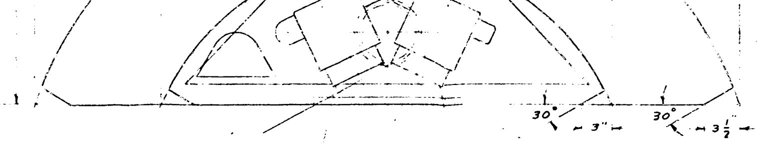
PRIMARY CAMERA

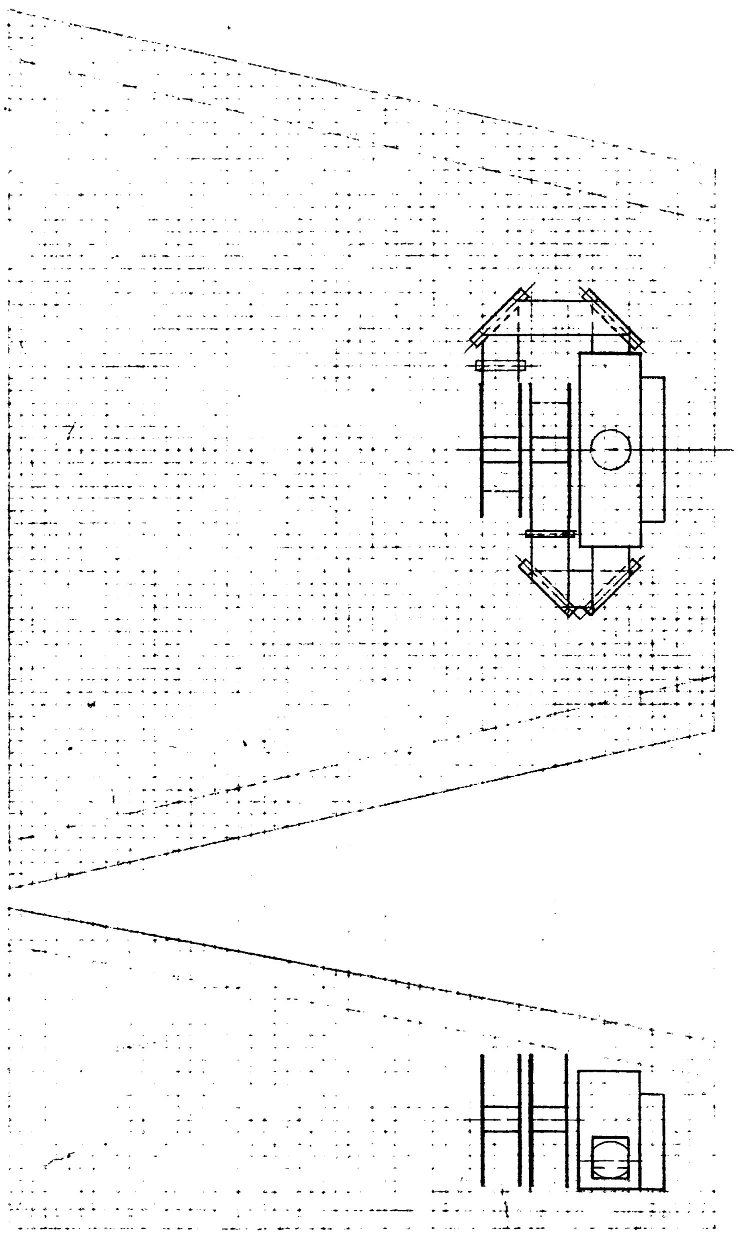
Format size 4-1/2 x 28-1/4" 19"
Film Footage 6,000 feet
Spool Diameter 20 inches.
Lateral Coverage 90°
Fore & Aft Coverage 14-1/4°
Window Size 11 x 44 inches

DUAL MAPPING CAMERA 3"

Format size 4-1/2" x 4-1/2"
Film 200 feet (each camera)
Lateral coverage 124°
Fore & aft coverage 74°
Window size 16 x 17 inches.

FIGURE 2





6" f4.0 LENS
70MM THIN BASE FILM
110° SWEEP ANGLE x 21° FORE & AFT
$2\frac{1}{4} \times 11\frac{3}{4}$ FORMAT SIZE
1500 FT. FILM
9" DIA. FILM SPOOLS.
9 LB. FILM
20# CAMERA
30# MISC. EQUIP.
6" x 17" WINDOW (MIN)

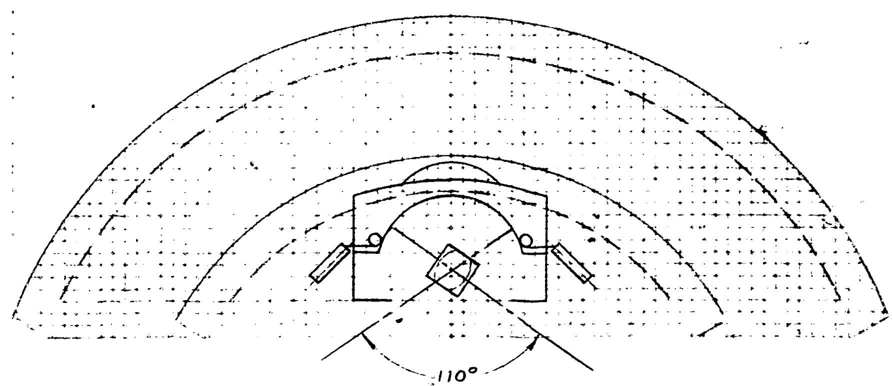



FIGURE 2A
ALT. #1

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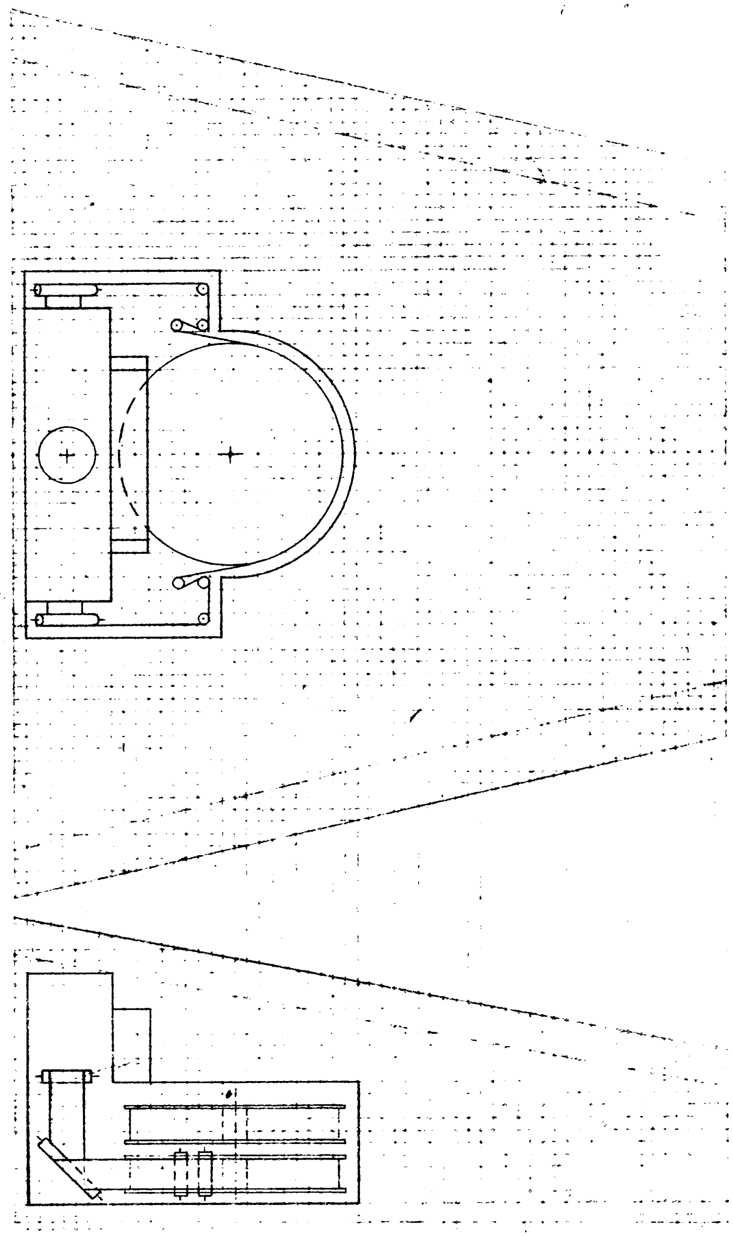

12" f/4.0 LENS
70 MM THIN BASE FILM
90° SWEEP ANGLE × 10¾° FORE & AFT
2¼" × 19" FORMAT SIZE
5000 FT FILM
18" DIA FILM SPOOLS
28½ LB FILM
40 LB CAMERA
32½ LB MISC. EQUIP.
5" × 15" WINDOW (MIN.)

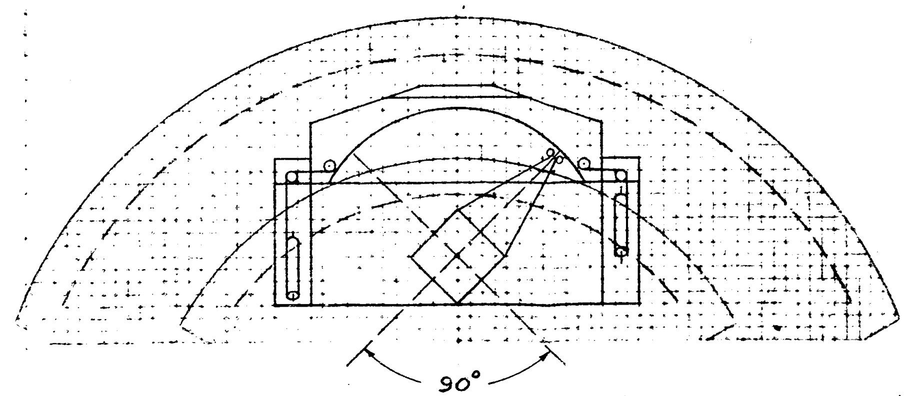


FIG 2B
ALT. # 2

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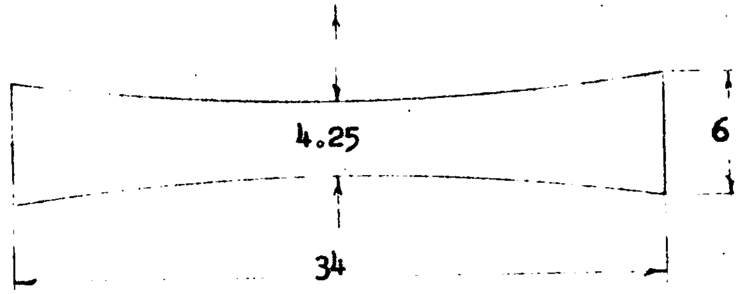
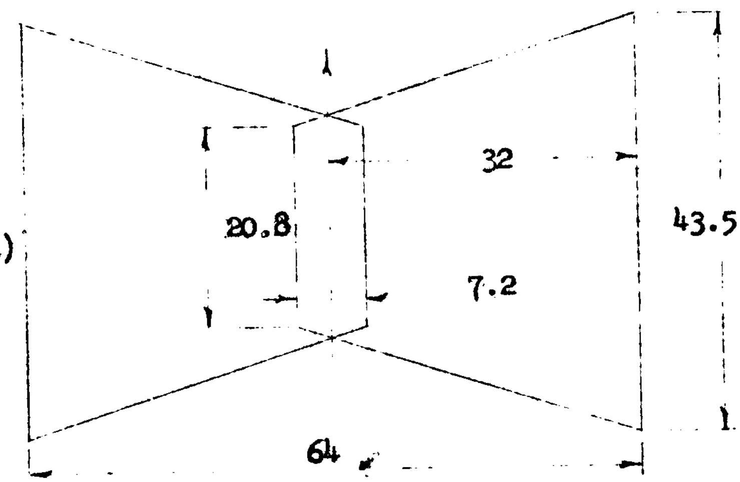
# GROUND COVERAGE OF CAMERAS

All dimensions given in statute miles

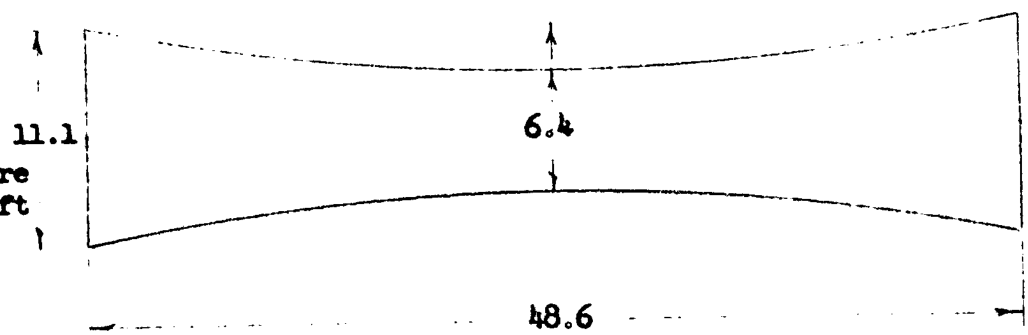
1. Primary Camera
   18" focal length
   5" film width
   90° lateral x 14-1/4° fore & aft
   4-1/2" x 28-1/4" format




2. Dual Mapping Camera
   3" focal length
   5" film width
   124° lateral x 74° fore & aft
   4-1/2" x 4-1/2" format (each camera)




3. 6" Alternate Camera
   6" focal length
   70mm film width
   110° lateral x 21° fore & aft
   2-1/4" x 11-3/4" format




4. 12" Alternate Camera
   12" focal length
   70mm film width
   90° lateral x 10-3/4° fore & aft
   2-1/4" x 19" format

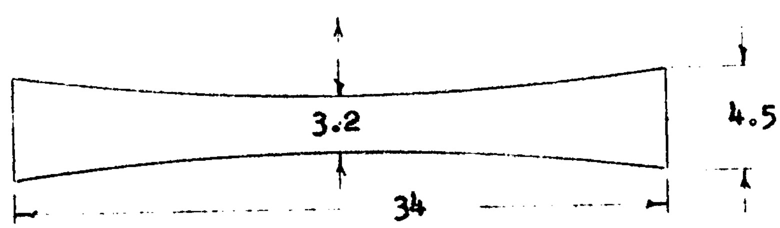



FIG 3

# SECTION III

## LENS SELECTION

### Primary Lens

The choice of lens for any optical system must be based on consideration of the fact that the lens is but one element in a cascaded system. The mathematical analysis of cascaded optical systems is well developed at the present time and may be used to select the lens for a particular application. The exact formulation of the analysis simply requires knowledge of the equivalent line spread functions of the various elements which are then convoluted and a Fourier transform made. The resulting Fourier transform has physical significance in that it is the actual frequency response curve of the overall system.

Utilizing this approach to determine the characteristics desired of the lens in a maximum acuity system, one finds that the ultimate in aerial image resolving power is not so important as the contrast with which images of larger dimensions are produced. In order that the lens exhibit the maximum values of response, it is necessary that image defects caused by aberrations be eliminated to the greatest degree possible so that the undulatory

nature of light will alone limit the perfection of imagery. Until recently this goal was attainable with lenses of significant aperture only over extremely small angular fields. However, utilizing the latest techniques in optical design and the aspherizing of surfaces, Dr. James G. Baker has succeeded in designing an f/4, 24 inch focal length lens which is diffraction limited over a 4-1/2 inch by 4-1/2 inch field. Consequently, it is proposed for this system of which the maximum in information capacity is required. This lens in an 18 inch f/4 version will resolve in excess of 200 lines/mm high contrast and over 100 lines/mm, low contrast, 2:1 ratio, on Kodak emulsion SO-1213.

Relevant to the use of such a lens is Fairchild's solution to the problem of maintaining high acuity cameras in focus even though the ambient pressure and temperature change. As is well known, the focal setting of a camera is a function of temperature and air pressure because of the variation of the relative index of refraction of glass and air and the thremal expansion and contraction of the metal components of the lens assembly and camera. The functional relationship must be found experimentally with considerable difficulty and may vary between cameras of

identical design and construction. As a result Fairchild has developed for high acuity cameras an automatic focusing technique based on auto collimation through the camera lens. An illuminated grid of alternate opaque and transparent lines in the focal plane, but outside the format, of the camera is imaged by the camera lens and dichroic mirror so as to fall on a similar grid also in the focal plane. Behind this second grid there is a photocell which produces an output signal when either grid is moved in the focal plane. The focal plane of the lens is automatically shifted, either by translating the lens along its axis or by changing the optical path by moveable wedges, until the phototube signal is a maximum indicating correct focus. The dichroic mirror permits the automatic focusing to be usable with infra-red so as not to affect the photographic transmission of the camera.

Mapping Lens

For the dual mapping cameras the proposed lens is a newly designed 3" f3.5 Precision Mapping Lens of exceptionally low distortion characteristics and extremely high photographic performance. On the proposed film emulsion (SO-1213). This lens will have resolution capabilities of the order of 60 lines/mm AWAR with image quality very much superior to existing mapping lens designs.

Lenses for 6" and 12" Auxiliary Cameras

The proposed lens for the 12" auxiliary camera will be a further miniaturization of the High Acuity lens used in the primary camera or slight modifications of this design retaining the same performance. In the case of the 6" auxiliary camera a new lens design is anticipated to utilize the latest state-of-the-art towards making this a high acuity system consistent with the mission to be performed.

# SECTION IV

## FILM EMULSION

As the film is but another element in the overall system, the comments made concerning the selection of the lens in the previous selection will apply. In this matter one must seek the solution which will provide maximum acutance within the exposure limitations imposed by the lens aperture, target luminance and imperfections in compensation for image motion. Analyzing the problem from this point of view, Fairchild has decided that the film emulsion, currently available, providing the optimum solution is Eastman Kodak SO-1213 or equivalent. Emulsions of this type have resolution capabilities in excess of 200 lines/mm at an ASA Exposure Index of approximately 12. This exposure index value will be considered in greater detail in Section VI, where exposure factors are discussed. Certainly, in view of advances which have been made in recent years in the quality of aerial emulsions, one can expect that further improvement will occur in the near future. The actual magnitude of improvement cannot be specified but it will no doubt be in the direction of increasing acutance without significant loss in emulsion sensitivity. Considering the elapsed time before any

system becomes operational, it is almost a certainty that an improved emulsion will become available for this system. This is greatly to be desired as the emulsion is one of the poorer elements in the system with regard to its effect on performance and any increase in its performance will immediately result in increased system capability.

## SECTION V

## IMAGE MOTION

Any relative motion between the image and the photographic emulsion during exposure will result in degradation of system performance because of the resulting blur. In general, the relative motion can be divided into three parts. The first arises from improper synchronization with the scan motion; the second, from platform angular instability; and the third, from the forward motion of the vehicle. The first source of error has been shown to be eliminated by the choice of the chimney-type panoramic design. With regard to the second, it is understood that the inherent steadiness of the vehicle is such that the obtainable ground resolution can be preserved for a satisfactorily high percentage of the time of flight without a stabilization mount. This is highly desirable as compensation for vehicle instability usually is one of the most significant design factors. Figure 4 shows the critical dependency of obtainable ground resolution on angular rates of motion of the vehicle about horizontal axes. The "starting resolution" values, shown at the lowest angular rates, are considered obtainable from the system proposed in these notes. As a result, forward motion of the vehicle remains as the sole significant source of image motion.

In order to track an image (Image Motion Compensation) with a fixed direction of translation of the lens or film, it is necessary for the image also to be in translation with an essentially uniform velocity over the format. Coincidence of the image velocity vector with the image velocity resulting from lens translation is assured by setting the IMC direction, shown in Figure 5, into the plane passing through the ground track. This can be done by means of rotating the mirror and the lens translation cam through the "crab" angle as described later in these notes. It is, however, necessary to provide the camera with two kinds of information, namely (1) the "crab" angle and (2) the ratio of vehicle velocity to altitude.

In the case where the vehicle has a self contained navigation system (for navigation over the earth's surface), or where it can have this information telemetered to it, a simple computer will serve to convert the relative ground velocity and altitude to the ratio required as on electrical signal to control the image motion compensation mechanisms. Further, if the "crab" angle (i.e. the angle between the relative ground velocity and the vehicle symmetry axis projected onto the horizontal plane) is available it can be transformed through the use of a servo to the combined mirror and cam angular position. If altitude informa-

tion is not available horizon sensors can be used to determine the earth's included angle with computation to establish altitude. This is a new and useful technique for high altitude vehicles which is incorporated in other developments in which Fairchild is engaged.

In the event that the craft flies an accurately known course then it would be possible to program the angle and the lens scan rates prior to takeoff or launch. This would be the lightest and simplest means of establishing the vector velocity to altitude ratio. Its use is dependent upon the known accuracy of the flight path, altitude and velocity.

The geometrical formulae which evaluate the blur, in terms of the pertinent stabilization and steadiness accuracies are presented in Figures 6 and 7. The mathematical analysis shows that for the longest exposure time (1/500 sec.) a resolution performance of 100 lines/mm low contrast requires that the rates of roll, pitch, yaw of the camera should be held to the limits indicated below.

| | |
|---|---|
| Roll, Pitch, Yaw Rates | 5 Minutes of arc/second |
| Roll, Pitch, Azimuth Angles | 1.4 Degrees |
| Image Motion Compensation Accuracy | 2% |

EFFECT OF VEHICLE STABILITY

on

GROUND RESOLUTION

for 18" focal length, 1/500 & 1/1000 sec. exposure

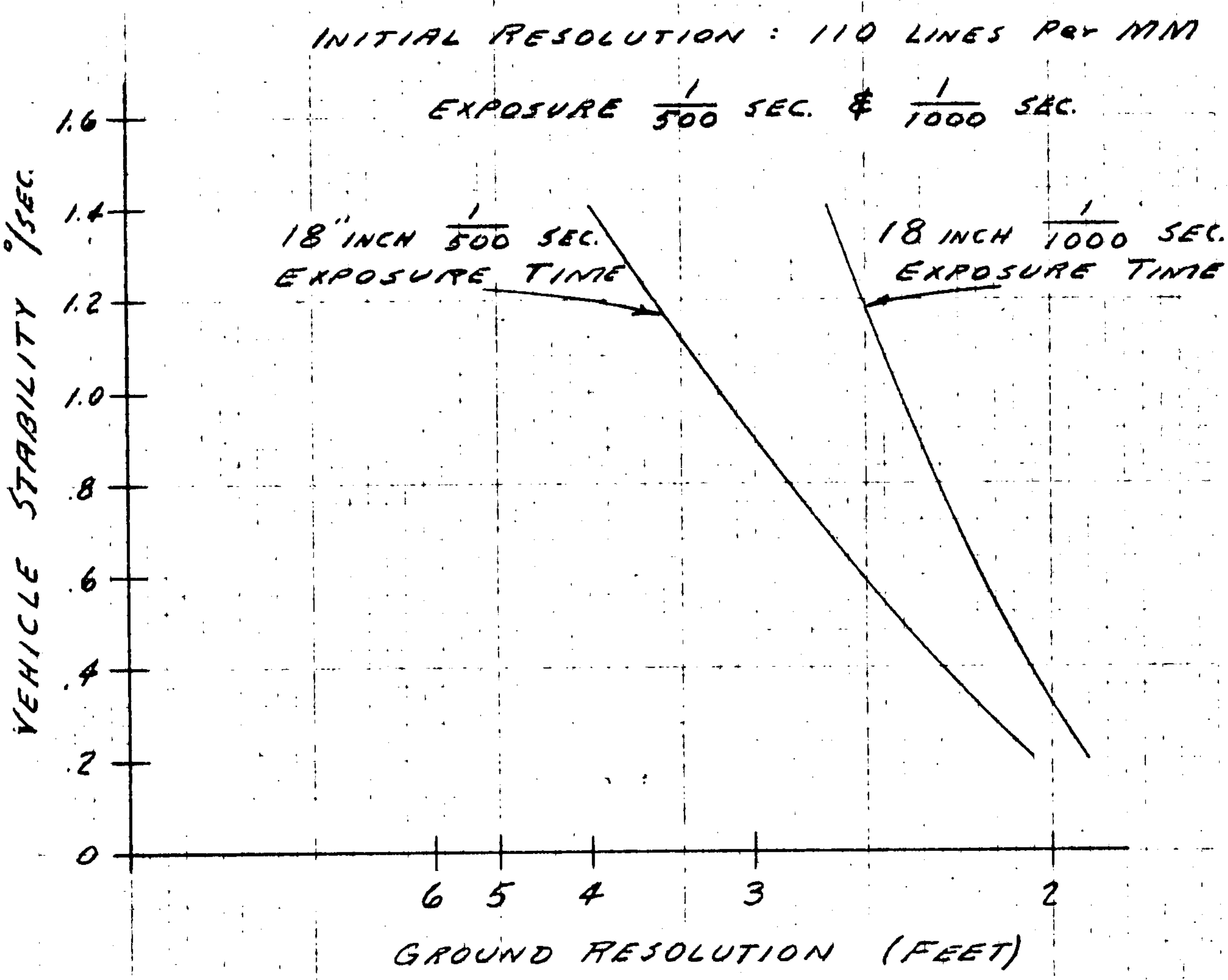



FIG. 4

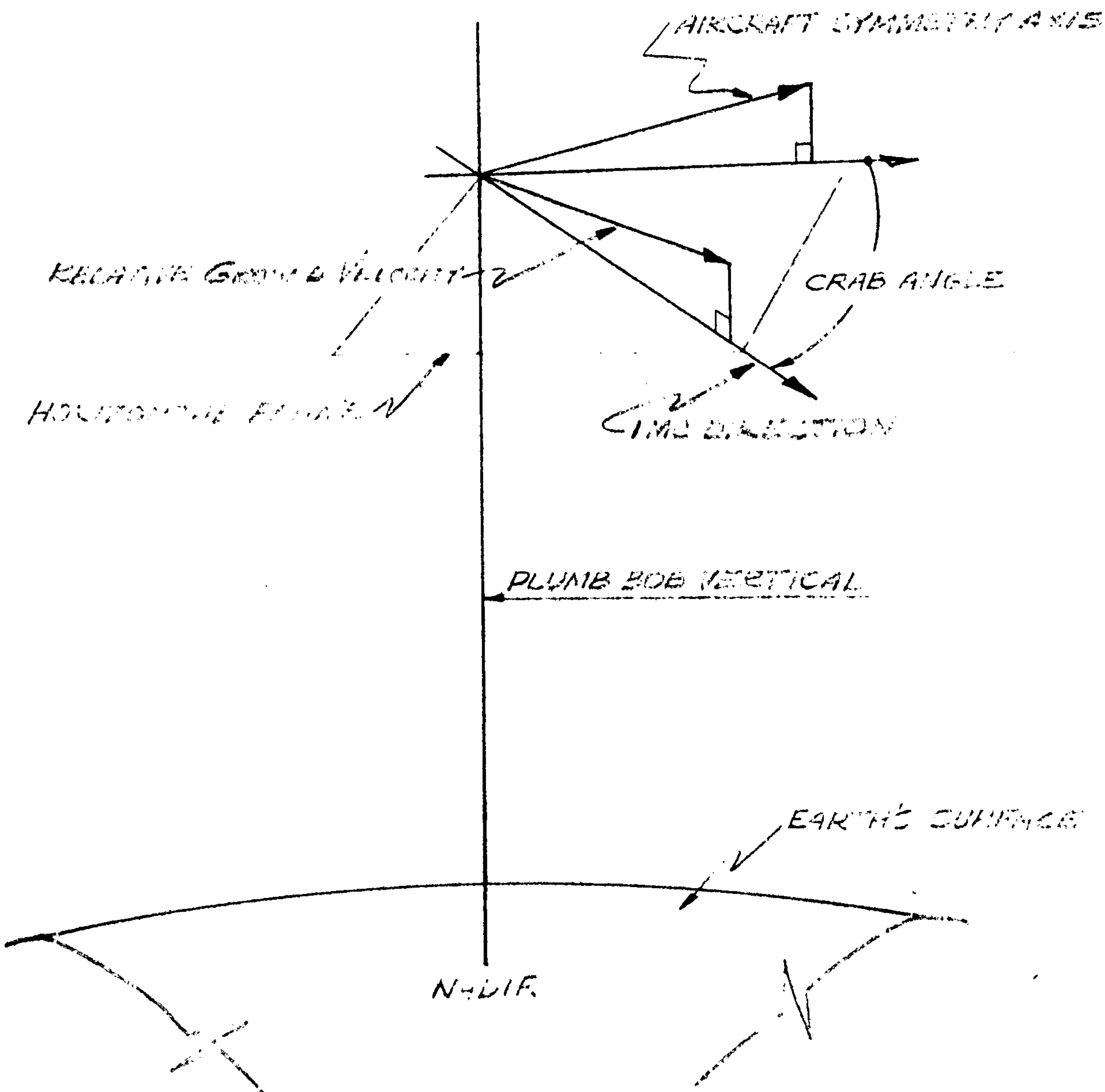



DIAGRAM OF RELATIVE VELOCITIES AND DIRECTIONS

FIG. 5

# GEOMETRIC RELATIONS

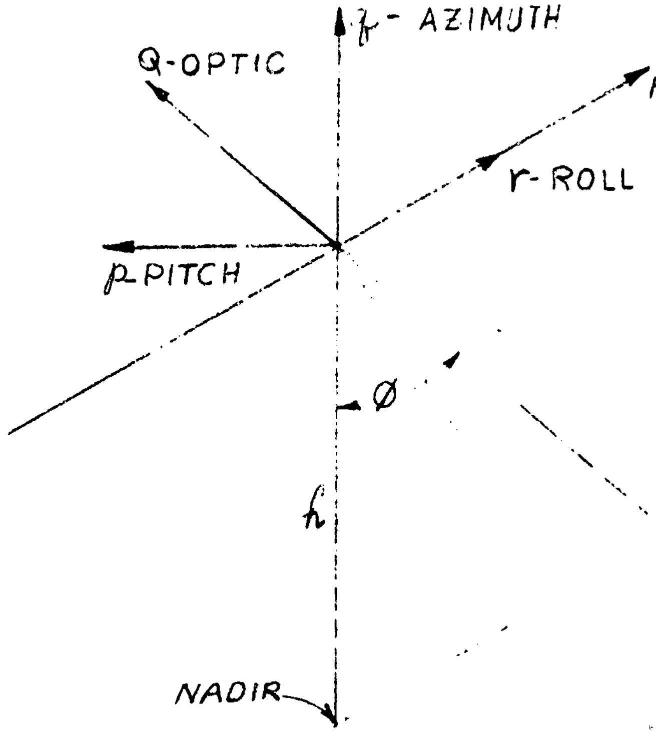



FIGURE 2

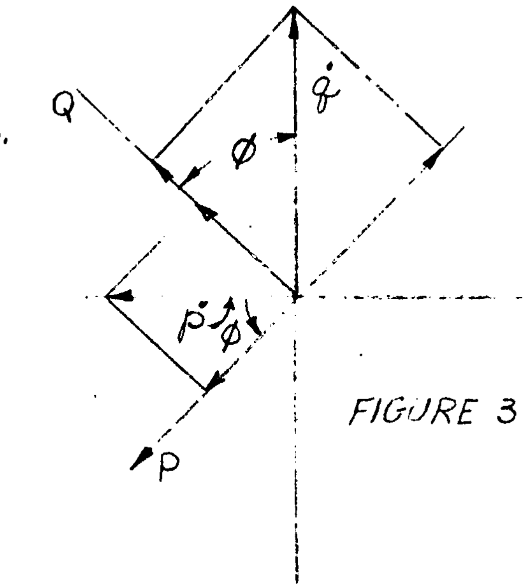
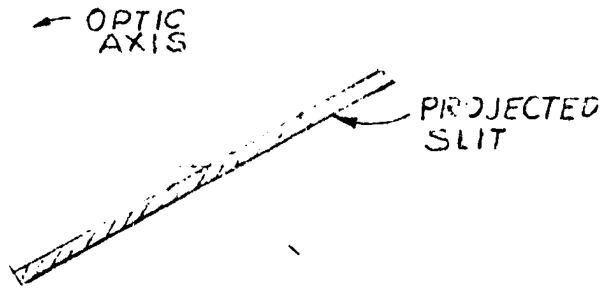



FIGURE 3




$$\text{SCALE} = \frac{f}{h}\cos\phi \qquad \text{I.M.C.} = f\,\frac{\dot{U}}{h}\cos\phi$$

$$\omega_P = (\dot{p}\cos\phi - \dot{q}\sin\phi) \qquad P = (p\cos\phi - q\sin\phi)$$

$$\omega_Q = (\dot{p}\sin\phi + \dot{q}\cos\phi) \qquad Q = (p\sin\phi + q\cos\phi)$$

$$\omega_R = \dot{r} \qquad R = r$$

$\dot{p}$ - pitch rate (rad/sec) $p$ - pitch angle (rad.)

$\dot{q}$ - yaw rate $q$ - yaw angle

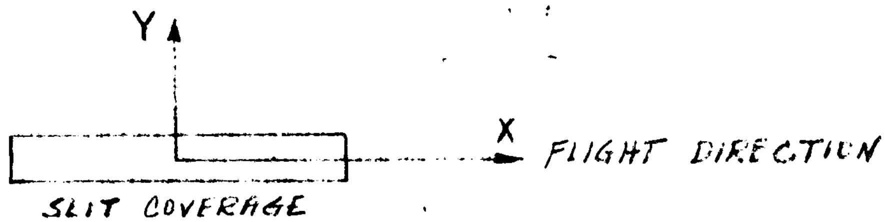
$\dot{r}$ - roll rate $r$ - roll angle

$h$ - altitude (ft) $f$ - focal length (in)

$\phi$ - ∡ between optic Axis & Vertical $\dot{U}$ - relative ground speed (ft/sec)

FIGURE 6

# BLUR FORMULAE




| | Y | X |
|---|---|---|
| $\omega_P$ | $0$ | $(\dot{p}\cos\phi - \dot{q}\sin\phi) f t$ |
| $\omega_Q$ | $(\dot{p}\sin\phi + \dot{q}\cos\phi) X t$ | $(\dot{p}\sin\phi + \dot{q}\cos\phi) Y t$ |
| $\omega_R$ | $\dot{r} f t$ | $0$ |
| $P$ | $(p\cos\phi - q\sin\phi)(\frac{\dot{U}}{h}\cos\phi) Y t$ | $(p\cos\phi - q\sin\phi)(\frac{\dot{U}}{h}\cos\phi) X t$ |
| $Q$ | $(f\frac{\dot{U}}{h}\cos\phi)(p\sin\phi + q\cos\phi) t$ | $(f\frac{\dot{U}}{h}\cos\phi)(p\sin\phi + q\cos\phi)^2 t$ |
| $R$ | $0$ | $(f\frac{\dot{U}}{h}\sin\phi) r t$ |
| I.M.C. | $0$ | $e_i \left(f \frac{\dot{J}\cos\phi}{h}\right) t$ |
| SYNC | $e_s V_f t$ | $0$ |

$e_i$ - FRACTIONAL ERROR IN I.M.C.

$e_s$ - FRACTIONAL ERROR IN SYNCHRONIZATION

$V_f$ - FILM VELOCITY $= \omega_{SCAN} f$

FIGURE 7

# SECTION VI

## EXPOSURE

In general exposure depends upon the major factors of scene brightness and brightness ratio at the camera, the spectral distribution of the image-forming light, film sensitivity, shutter speed, aperture, film processing, time of day, month of year and cloud cover.

An investigation has been made into the limitations which would be placed on the operational use of the system as a function of the anticipated shutter speeds. The results are shown in Figure 8 which indicates that with certain other conditions stated (as in the figure) photography is improbable only at the higher latitudes during the winter months.

It is to be noted that the curves of Figure 8 are based on an Exposure Index of approximately 12, which is correct for optimum conditions of atmospheric haze. However, at high altitudes, one is often apt to be faced with conditions somewhat less than optimum. This increased haze will often result in a compression of the range of ground luminance to be recorded. As the exposure is determined by the minimum scene luninance, the exposure under such conditions can be reduced, resulting in

an effective increase in the Exposure Index. Increases of two to five are not uncommon. As a result, the 1/200 second curve is probably more representative than the 1/500 second curve in assessing the exposure capabilities of the system.

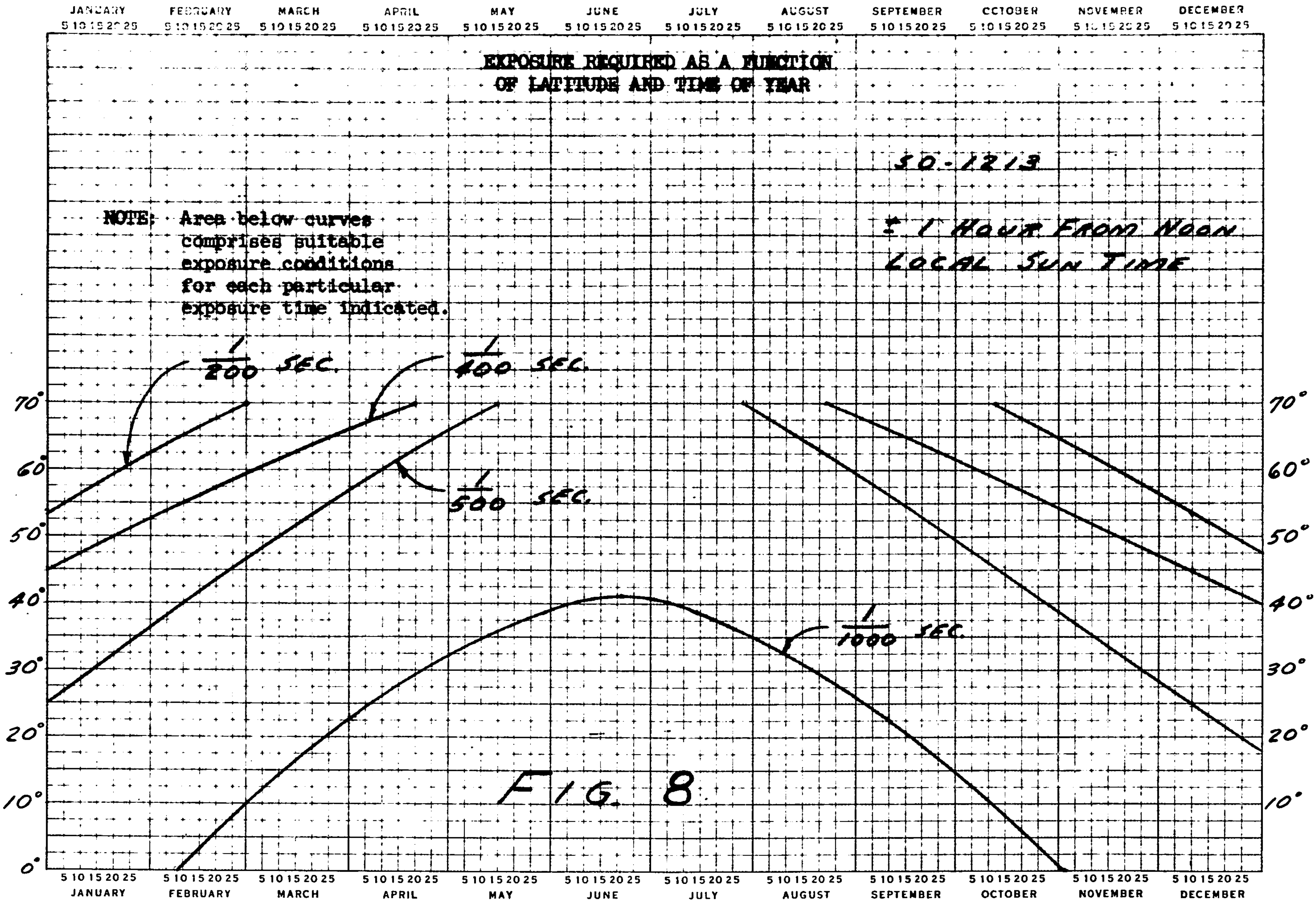



FIG. 8

FAIRCHILD CAMERA AND INSTRUMENT CORPORATION

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## SECTION VII

## FILM CAPACITY

The required film capacity for the proposed system is based on the following conditions:

V = Vehicle Velocity = 3880 feet/second

H = Vehicle Altitude = 90,000 feet.

L = Film format in flight direction (inches)

% = 1 - % overlap (60% overlap).

T = Time of photographic mission = 6,000 seconds

f = Focal length of camera (inches)

$\Theta$ = Lateral angle of scan of panoramic camera (radians).

K = Conversion factor (inches/foot).

For these conditions the film footage required may be derived as follows:

$$\text{Film Footage} = \frac{V \times f^2 \times T \times \Theta}{H \times K \times L \times \%} \qquad (1)$$

This equation may be plotted with Film Footage, focal length, format size, and lateral angular coverage as a variable as shown in Figure 9.

For the particular values assumed above the plot indicates the solution for the following selection of focal length film width and scan angle.

18" focal length

5" film (4-1/2" format)

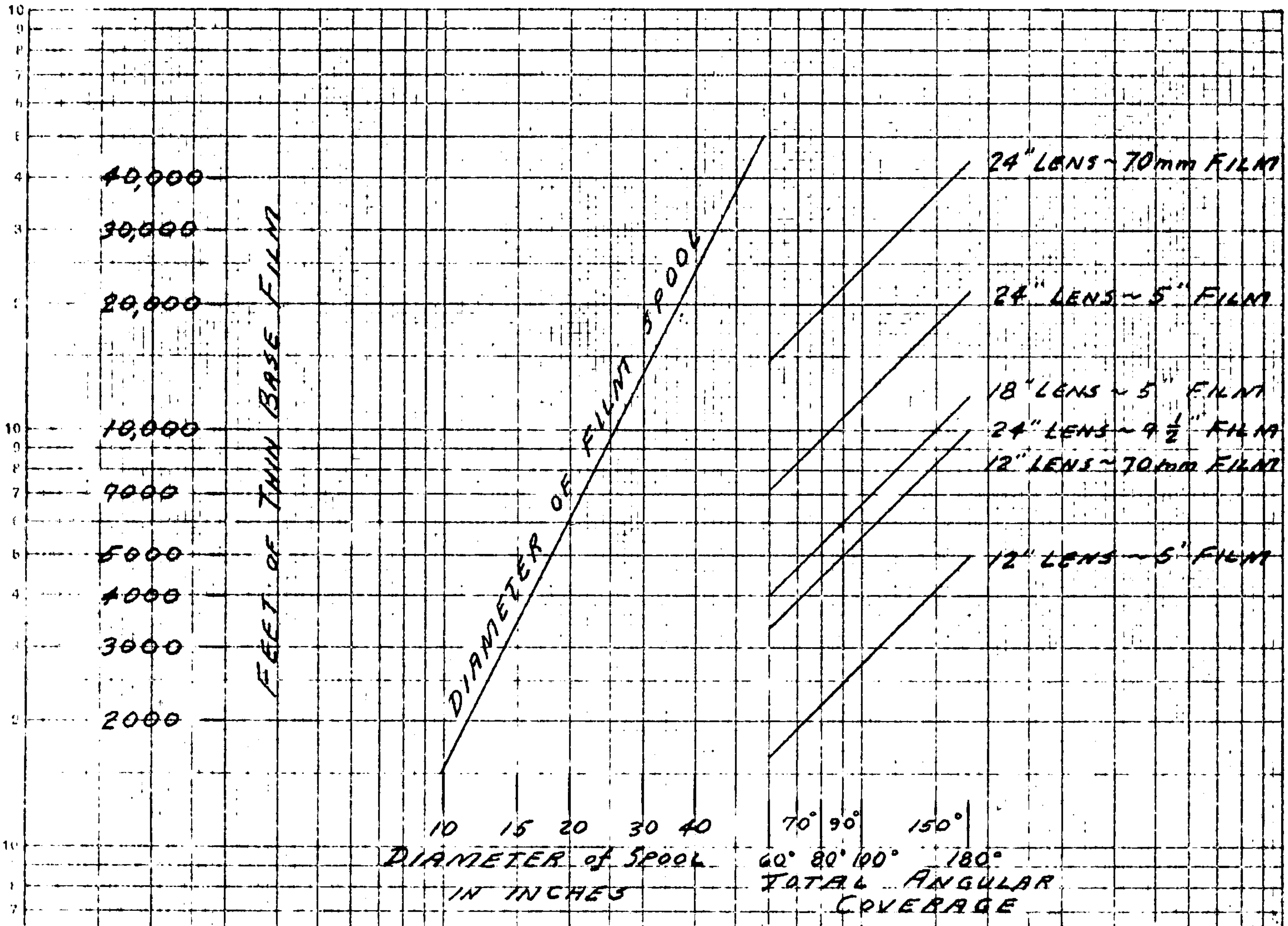
90° lateral scan angle.

As indicated this requires 6,100 feet of film. For configuration planning, the spool diameter is of immediate concern and the second reference line on Figure 9 may be used to determine this value (20 inches in this solution).

Other values of focal length, film width, and lateral scan angles may be selected and the resulting film footage obtained.

As will be noted in Equation 1 and Figure 9 the film footage increases as the square of the focal length. For some of the extremes of focal length and film widths shown the resulting spool diameters become intolerable in the space allotted.

For the purpose of estimating the effect on system weight of different coverage requirements, figure 10 gives film weight as a function of film length for thin base film.




**FILM SPOOL DIAMETER** as a function of (1) focal length, (2) film width & (3) angular coverage.

Under conditions of (1) Velocity M 4.0, (2) Altitude 90,000, (3) Time 6,000 seconds, and (4) 60% overlap.

FIG. 9

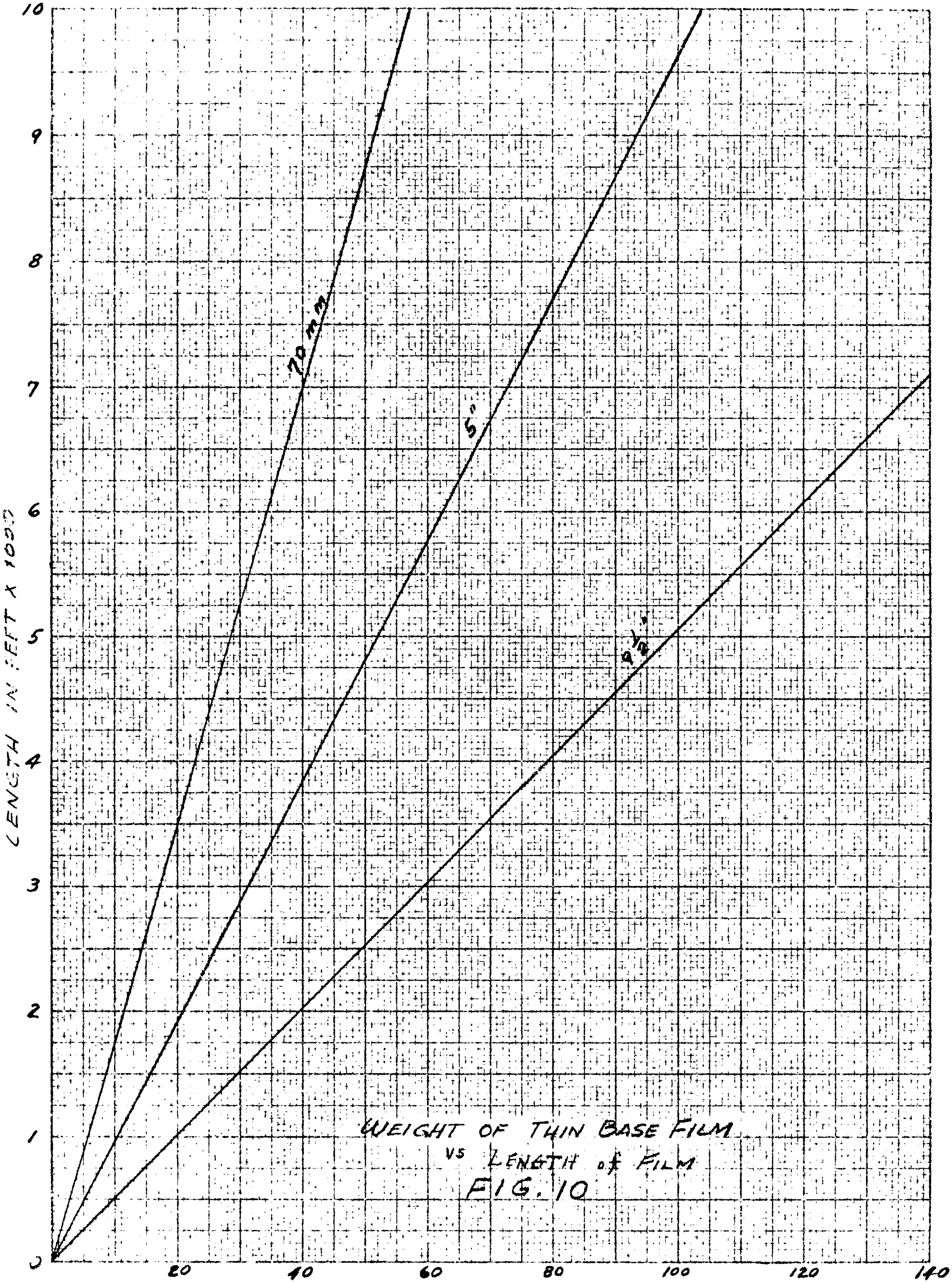

LENGTH IN FEET X 1000
0
1
2
3
4
5
6
7
8
9
10
20
40
60
80
100
120
140
70 mm
5"
9 1/2"
WEIGHT OF THIN BASE FILM
VS LENGTH of FILM

FIG. 10

## SECTION VIII

## EFFECTS OF SHOCKWAVE, BOUNDARY LAYER AND WINDOW DESIGN

In view of the fact that any aerial photographic system must look through the shock wave and boundary layer attendant upon high Mach number of the carrying vehicle, it is necessary to consider what optical distortion might result.

With regard to the shock wave, analysis shows that, while the ratio of air densities across the shock is large, the actual change in density is small at high altitudes. Since the index of refraction of air is a function of the air density, the change in index across the shock is so small that its effect on system distortion will be negligible. Because of the small value of air density at high altitudes, similar comments apply with respectto the effect of the boundary layer on distortion.

Of greater importance in system performance is the heating of the system window because of heat transfer from the boundary layer. At the Mach numbers and altitudes under consideration, the surface temperature of the window together with the bending effect of aerodynamic loads may also be the cause of index of refraction gradients throughout the window. Both of the above will have an

adverse effect on system performance and must be guarded against. One method of accomplishing this result is to fabricate the photographic window of two pieces of glass with a vented airspace. By this means there will be no pressure differential across the heated outer window to cause distortion. Because there is no pressure differential this outer window can be relatively thin, thus minimizing the effect of index gradients.

The actual design detail of the optical windows can only be done after discussion with the vehicle designers. It is improbable that large single windows can be used. However, this is not an unusual design limitation and has been studied in detail by Fairchild. For example, the long window for the primary camera can be in sections, separated by narrow longerons or mullion strips so positioned that one of these dividing strips is always in the field of view of the lens. This arrangement gives even exposure and has minimal effect on system resolution.

Methods of coverage for window protection on take off and landing have also been worked out in general design. Here again, the actual detail will have to be worked out with the vehicle manufacturer.

The material for the photographic windows will be either fuzed quartz or one of the newer optical window materials currently under development at Corning Glass.

## SECTION IX

## ENVIRONMENTAL CONSIDERATIONS

One of the initially postulated ground rules for this reconnaissance system was that the camera compartment would be pressurized and temperature controlled. Since that time, however, questions have been raised as to what would be the camera performance without such controlled environment.

Insofar as electrical and mechanical operations are concerned, the cameras can operate over a temperature range of 50°F to 120°F. The cameras can also operate in the external ambient pressure conditions. From an acuity standpoint, however, changes in temperature and pressure during the flight will materially affect the acuity of the cameras despite best design practice for such conditions.

# SECTION X

## AUXILIARY AIRBORNE EQUIPMENT

### Velocity and Altitude Consideration (V/H Signals)

The attainment of a high acuity photographic record from a supersonic vehicle flying at a finite distance above the earth's surface requires that provision be made for compensation of relative ground motion.

If altitude and ground speed can be programmed in advance of the mission for the duration of the reconnaissance portion of the flight profile, this programmed data can be used to command a forward motion compensation mechanism. If this is not the case, however, then continuous determination of altitude and ground speed should be provided.

Commonly, these variables are derived from the aircraft navigation subsystem and from radar altimetry, and combined in a simple computer to provide the Vg/H command signal to the forward motion compensation mechanism.

A Doppler Radar which is representative of advanced state-of-the-art, which may be extended in capability sufficient for the present purpose, is the AN/APN-115. Present design specifications

for this equipment which is now under development indicate an operational capability of measurement of ground speed to ±0.005% (which is in excess of the accuracy required) at the present maximum design velocity of 1800 knots. This equipment can also provide measurement of drift angle to within ±1.5 minutes of arc. This latter measurement can be used to position the aiming mirror in front of the camera to compensate for "crab" as described elsewhere in this proposal.

With respect to determination of altitude present radar altimetry capabilities appear to be limited to 60,000 feet altitude (AN/APN-~~66~~110). Here, however, advantage might be taken of the high altitude of the vehicle wherein determination of altitude may be accomplished by measurement of the angle between the apparent earth horizon and the true horizontal plane. This might be accomplished by use of the horizon scan package shown in Figure 2.

Automatic Exposure Control

Automatic exposure control will be provided for all cameras and will be of standard proven design.

Data Recording

In the proposed system both panoramic cameras and dual mapping cameras will be supplied with auxiliary data recording.

In the case of the panoramic cameras, provision can be made for horizon camera recordings similar to techniques used on another program with Fairchild. In addition, recording can be provided for: (1) timing marks along the film; (2) film shrinkage marks; (3) time furnished by auxiliary timer; (4) vertical or nadir recording and (5) camera identification.

In the case of the dual mapping camera recording of the following information can be made: (1) camera identification; (2) latitude; (3) longitude; (4) time; (5) altitude; (6) camera attitudes at exposure.

Camera Control System

It is assumed that the vehicle will be occupied by a single man and hence the assumption that he will have little time to apply to camera control problems. Therefore, the cockpit part of the control will be limited to an on-off switch, operating signal indicators, film capacity remaining, and supplementary over-riding controls for contingency use.

The major portion of the camera control system will be automatic in providing warm-up, cycling signals, V/H signal, data recording signals and control, and cut-off.

# SECTION XI

# GROUND SUPPORT EQUIPMENT

## Test Equipment

Ground test equipment will be provided for pre-flight check-out. This test gear will be in mobile form so that it can be used on the flight line, in the hangar, or equipment laboratory. It will provide all the necessary go-no-go information as well as confirmation of electronic control circuitry performance in terms of voltage and current consumption.

## Film Processing

Film processing equipment can be provided for field use. This equipment will be of proven reliable design. This gear can be of either standard large colume water consumption types or special designs using a limited amount of water.

## Obtaining Quantitative Information from Panoramic Aerial Photographs

Several papers and reports have been written on the general subject of obtaining quantitative information from panoramic photography. In general, these have been limited to a theoretical analysis with little concern for the hardware to accomplish the tasks involved. It has been considered to the point of a realization that certain equipments, such as a precision screw comparator,

are impractical for efficient use except on photographed objects of exceptional importance.

In the concept of functional ground support equipment for the proposed system, Fairchild has considered various types of equipment which vary in complexity and accuracy from a single frame panoramic measuring device for target location to a stereoscopic plotter for continuous plotting from panoramic photography.

Equations (1) and (2) completely define the geometric relationship between the plane tangent to the earth's surface at the nadir point and the panoramic photo coordinates. Symbols are given in Figure 11.

When requirements for the greatest possible accuracy of ground location exist, equations (1) and (2) must be satisfied either by computational or precise instrumental means, such as the Optical Angulator proposed by Fairchild in SME-CG-9 dated November 1958 previously submitted.

In situations in which extreme accuracy is not important, assumptions may be made resulting in simplified instruments and procedures. For instance, if it is assumed or determined that the camera was vertical during the exposure period, which may be possible in the proposed installation, equations (1) and (2) may be simplified considerably as indicated by equations (3) and (4). These

$$X = (H-h)\frac{\left[f\cdot\cos(\tan^{-1}\cdot\tan R\cdot\cos\phi)\sin\phi\right]-\left[f\cdot\tan y/f\cdot\sin(\tan^{-1}\cdot\tan R\cdot\cos\phi)\sin\phi\right]+\left[x\cdot\sec y/f\cdot\cos\phi\right]}{\left[f\cdot\cos(\tan^{-1}\cdot\tan R\cdot\cos\phi)\cos\phi\right]-\left[f\cdot\tan y/f\cdot\sin(\tan^{-1}\cdot\tan R\cdot\cos\phi)\right]-\left[x\cdot\sec y/f\cdot\sin\phi\right]} \quad (1)$$

$$Y = (H-h)\frac{\left[f\cdot\sin(\tan^{-1}\cdot\tan R\cdot\cos\phi)\right]+\left[f\cdot\tan y/f\cdot\cos(\tan^{-1}\cdot\tan R\cdot\cos\phi)\right]}{\left[f\cdot\cos(\tan^{-1}\tan R\cdot\cos\phi)\cos\phi\right]-\left[f\cdot\tan y/f\cdot\sin(\tan^{-1}\cdot\tan R\cdot\cos\phi)\right]-\left[x\cdot\sec y/f\cdot\sin\phi\right]} \quad (2)$$

where $(H-h)$ = terrain clearance of point in question

$f$ = focal length of camera

$x, y$ = photo coordinates - origin at center of span

$R$ = Angle of roll about flight axis

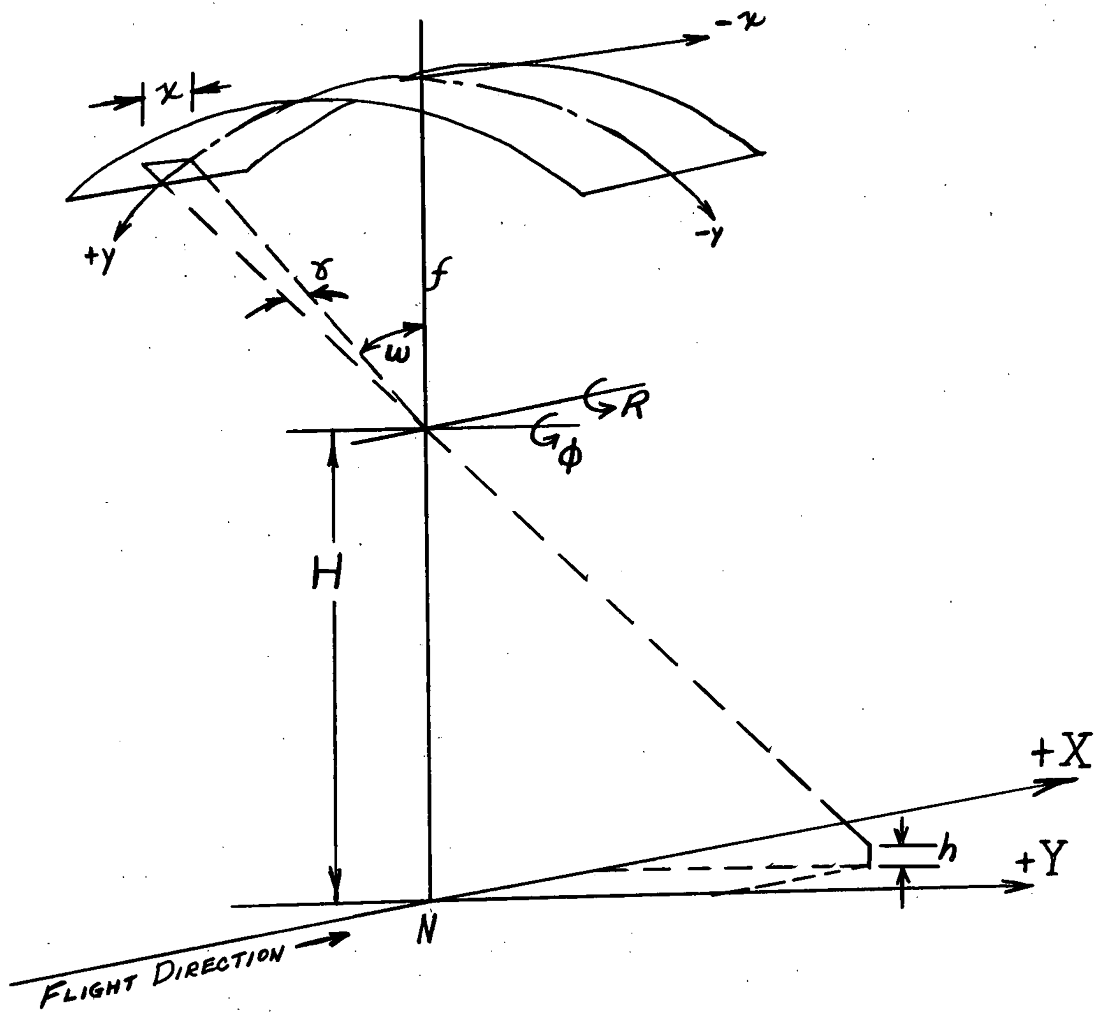
$\phi$ = Angle of pitch about horizontal transverse axis

$X, Y$ = Ground coordinates with nadir origin and X axis parallel to flight line

$$X = (H-h)\, x/f \sec y/f \quad (3)$$

$$Y = (H-h)\tan y/f \quad (4)$$

EQUATIONS FOR DETERMINATION OF GROUND COORDINATES
FROM PHOTO COORDINATES OF PANORAMIC PHOTOGRAPHY




SYMBOLS USED IN PANORAMIC PHOTOGRAPHS

FIGURE 11

expressions may be handled in a comparatively simple mechanical measuring device to read out in terms of ground coordinates or in terms that require only multiplication by the altitude above terrain for ground coordinate values.

Panoramic Photo Restituter

As a direct result of Fairchild's design and construction of an electronic rectifier for Rome Air Development Center, we have now worked out a basic invention for restitution of high acuity panoramic photographs.

This proposed restituter satisfies the mathematics of the requirement that the two dimensions of the photograph be distorted according to a transformation function. Its output is a restituted positive print or transparency with or without enlargement.

The restituter is strip or sheet fed with the transformation from negative to positive being a continuous photo-optical process. The machine operation is controlled by a relatively simple computer. The device will also remove the "S" curve effect inherent in panoramic photography from a moving vehicle.

This proposed equipment will have the advantage of high resolution

high photographic speed, high versatility and inherent high reliability. Inasmuch as this is a very recent invention, a separate detailed proposal is being prepared on the device and will be available for Government consideration in the latter part of March 1959.

Dual Mapping Camera Ground Support Equipment

The extraction of intelligence information from the dual mapping camera installation will use conventional photogrammetric and photo interpretation techniques currently used for twinplex stereoscopic mapping. Existing stereoscopic plotters, such as the Balplex, Kelsh or Twinplex used with these techniques utilizing lateral twinplex coverage can be used with only slight modification, if any, depending on the model of the particular plotter being considered. Conversion from the three inch focal length to that which is used in the standard plotter can be accomplished by a precision ratio printer.

## SECTION XII

## INFRARED SENSORS

In order to achieve a maximum of useful information, the inclusion of an infrared ground scanning system is highly desirable even though the IR system may be capable of only limited resolution. The correlation of the IR data with that obtained from the photographic sensor improves interpretability and provides information not otherwise obtainable. The great advantage of such a two-color system is that the photographic channel supplies an easily recognizable terrain picture, within which the infrared "hot" target can be accurately located and its significance ascertained. Two and three color electro-optical systems have been advocated by Fairchild for over six years, e.g. the Scan-A-Con System; and large amounts of company research and investigation have gone into such systems.

Although much of the sensor compartment is filled with the primary and secondary cameras, there is still adequate space for an IR scanner, recorder and the associated electronic components. The only major question yet unresolved is that of background radiation originating in the IR window of the system. This problem arises because of aerodynamic heating of the outer surface

of the vehicle. It is understood that for this particular application, the window temperature may be approximately 700°F. From black-body calculations it is found that the wavelength at which peak emission occurs for this temperature is 4.5 microns. This unfortunately falls within the 3 to 5 micron atmospheric window and requires consideration. However, this problem which is common to many IR systems has been discussed with two companies highly experienced in this field, with whom Fairchild has been working on unsolicited IR proposals, and they feel that the problem is soluble. Part of the solution depends upon the fact that the actual power emitted from the window as background is a function not only of temperature but also of emissivity. As the sum of emissivity, reflectivity and transmissivity is unity for all materials, the selection of a window material of maximum transmissivity for the wavelength interval in which the detector is responsive will insure minimum background radiation. The responsivity of the detector will be limited to the 3-5 micron atmospheric window by appropriate bandpass filters. The extraneous window radiation can be further reduced by lowering the temperature of the window by internal cooling and by altering the aerodynamic flow pattern in the vicinity of the window so as

to decrease heat transfer from the boundary layer. The extent to which the latter may be employed depends on whether or not the vehicle designer will be able to stand the slight increase in aerodynamic drag attendant to the alteration in shock wave and boundary layer characteristics. The cited opinion with regard to the feasibility of overcoming this difficulty is based in large part on fundamental studies for IR sensing from Dynasoar. In any event, there is more than sufficient probability of success to warrant inclusion of detailed study of IR as a portion of the system capability in Phase I of the program.

The IR sensor would be designed to work in the 3-5 micron region. It is considered that the thermal problems discussed above will preclude any possibility of working in the 8-13 micron region as this would require an extremely cool window. The scanner would be of the line scan type covering a lateral angle of 90°. Recording would be on film using either a cathode ray tube recorder or the ultrasonic light modulator. The choice of recording technique would depend on the resolution, bandwidth and dynamic range required.



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The resolution of the IR scanner will be at least one milliradian resulting in a 90 by 90 feet ground resolution element at operating altitude.

In view of the fact that the IR information will be correlated with that obtained photographically, an increase in IR resolution would not cause confusion in interpretability as is sometimes the case with independent IR systems. However, because of the limited space available in the vehicle, the present state of infrared technology with regard to detector sensitivity, time constant and other factors restricts the angular resolution to a value of approximately 1 milliradian. Further improvements in the performance of detectors such as indium antimonide or gold-doped germanium would result in reducing this system limit and would be incorporated should they become available in sufficient time. At the present time improved resolution can be obtained only by the use of multiple detector arrays with the attendant increase in system size and weight.

At a resolution of 1 milliradian the scan rate becomes approximately 39 scans per second (velocity of 3884 feet per second) a figure which is low as regards the capability of

mechanical scanning techniques. For a 90° scan at 1 milliradian resolution, the number of picture elements per scan line is approximately 1600. At 39 scans per second a bandwidth of 31 kilocycles is required. This bandwidth, with proper gamma control circuitry, is well within the recording capability of the Fairchild cathode ray tube recording system.

The required film capacity for a 90° scan system of 1 angular mil resolution will be approximately 32 feet if 70mm film is utilized.

Referring now to other details, the use of indium antimonide in the photoconductive mode for operation in the 3-5 micron spectral region will require liquid nitrogen cooling. The cell itself will be mounted in the now customary miniature Dewar flask. The amount of liquid nitrogen required will be minimal. Because of the extended operation time study will be required to ascertain the feasibility of utilizing a small cryostat for this cooling which would be very convenient. However, recent developments in indium antimonide detectors based on the photo-electric-magnetic or Hall effect may permit the use of an uncooled cell in a system of limited resolution.

The opto-mechanical design of the scanner can take many forms considering the scan rates involved. Preferred forms are oscillating mirror types with low drive power requirements for large apertures. One arrangement is positively driven at a controlled rate; the other is based on a resonant frequency drive. Both are of extremely light weight construction and are capable of compact configuration. The two drives are illustrated in Figures 12 and 13. The resonant frequency drive is the more compact and is therefore particularly desirable because of the smaller external window.

The electronic circuitry will include a power supply, preamplifier, gamma control and probably a quantizing network for enhancing contrast as an aid to interpretability and to reduce bandwidth requirements. All of the above can be highly transistorized for reliability, compactness and weight reduction.

Dependent upon the inherent stability of the vehicle, it may be required to record instaneous altitude data (roll, pitch and yaw). These data will be used in ground support equipment for automatically rectifying the IR information for correlation with the photographic record. Providing the required correction

on the ground will reduce the complexity of the airborne recorder.

A 1 to 1/2 mil 90° system will weigh approximately 40 to 60 pounds and require a volume of about 1-1/2 cubic feet. This cubage is made up of the scanner, recorder and associated electronic components.

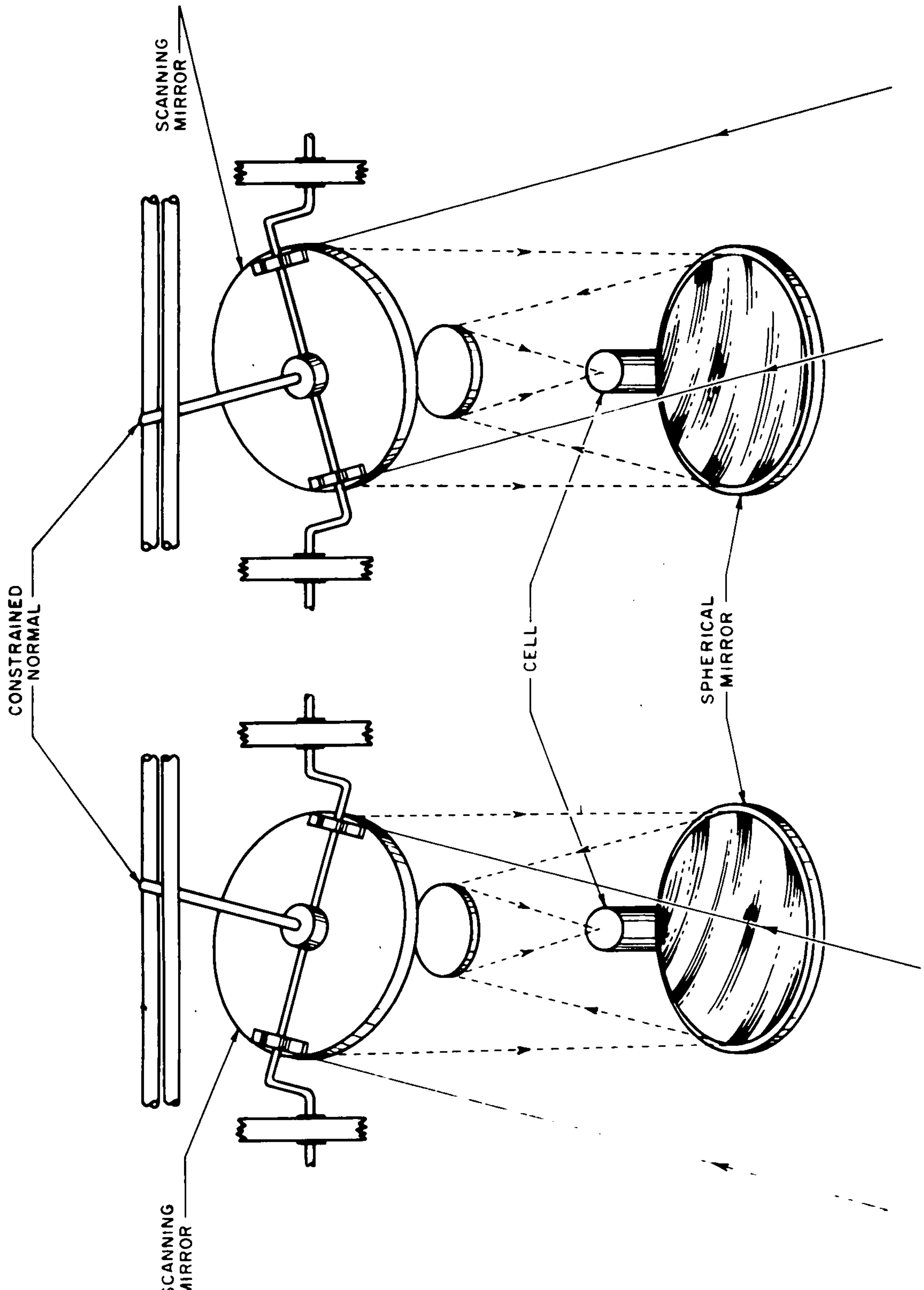
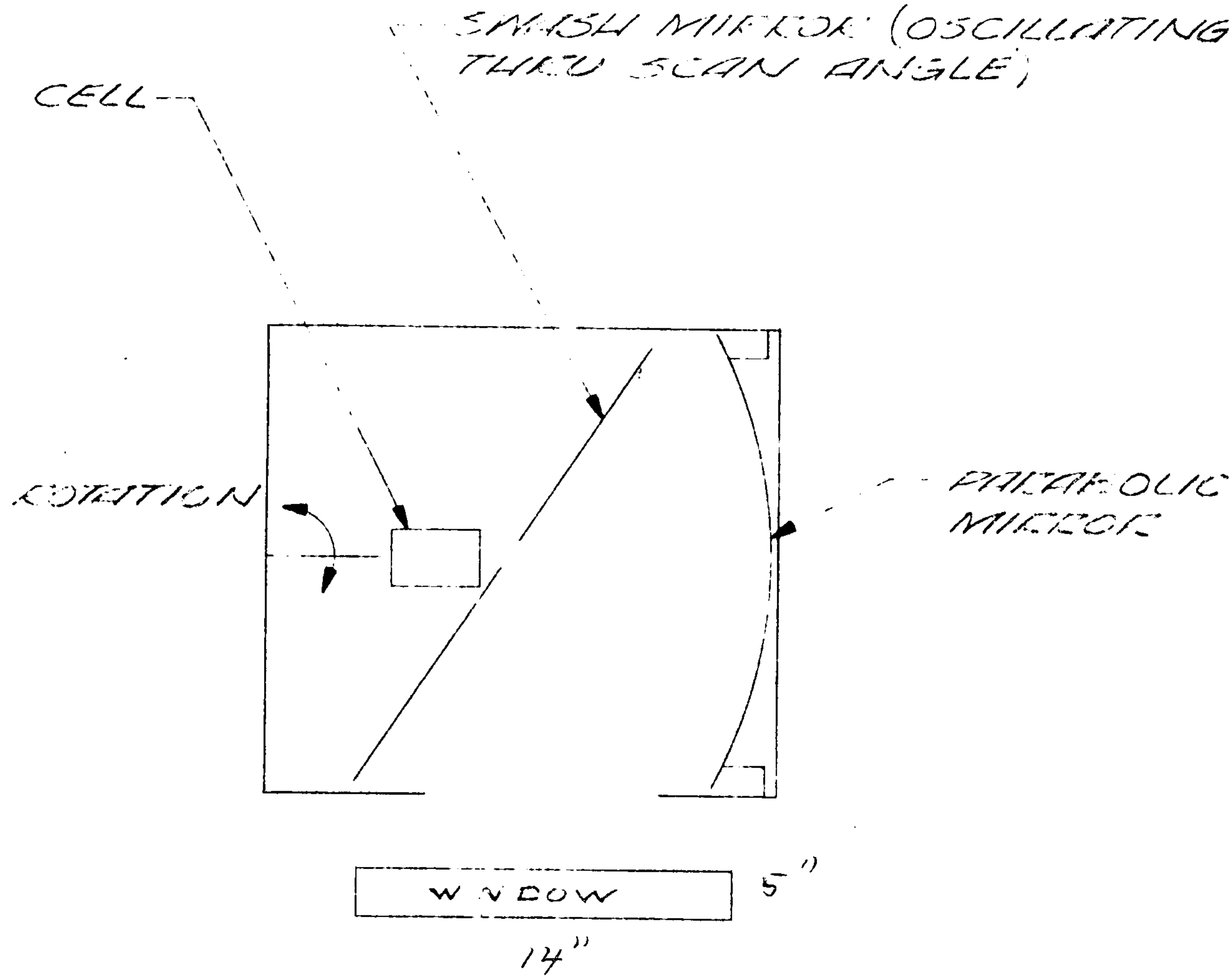



DIAGRAM OF CRANK SCANNER OPERATION

FIGURE 1 2




SCHEMATIC OF RECONNAISSANCE SCANNER
FIG. 1

March 3, 1959

Dear George:

Enclosed is a proposal, in a very preliminary form, for a camera, or rather a family of cameras each basically like the other in most respects. You indicated little time could be allowed to us for getting this to you; therefore, it is at best more fragmentary than we normally like to see leave our hands.

We believe the design we have in mind will give the best of results and in the long run be more reliable than almost any you can imagine. It is flexible enough to be used at low altitudes right on up to the range of satellites with only minor changes. With some changes in-flight processing and scanning are possible. Thus, it becomes a very flexible tool to go with various vehicles as they are evolved. It also can accept improvements in the elements of the system as they come with little design rearrangement. This flexibility, coupled with highest resolution pictures and reliability, deserves your very careful attention because we doubt it can be surpassed readily now.

We believe you should have first usage of this design and would like to have an expression of your interest.

Because some parts of this design may be proprietary and [illegible] of the details are dependent upon combinations of concepts we [illegible] not had time to study fully, we would prefer that you retain [illegible] thoughts within your own organization. Under certain circum[illegible] we would consider waiving our proprietary interests.

ILLEGIB

[redacted]

[illegible]closures:

(1) Attachment A
(2) Figures 1 - 5 (incl.)

## A RECOMMENDATION OF PHOTOGRAPHIC RECONNAISSANCE EQUIPMENT

## FOR USE IN HIGH FLYING AIRCRAFT

The recitation of the operating conditions of the aircraft in mind is being omitted intentionally here, though the general values are evident in the calculations which are used. Therefore, some specifications are assumed from which those applying to any particular program can be extrapolated.

| | | |
|---|---|---|
| Aircraft speed | - | 3,000 feet per second |
| Aircraft altitude | - | [redacted] |
| Photographic recording time | - | 15,000 seconds or 4 hours |
| Desired ground resolution | - | 2 feet (in photographic terms) |
| Area photographed | - | continuous strip x 10,000 feet to 50,000 feet wide |
| Types of photography | - | black-and-white (future addition of color); stereo and IR (rough resolution) for correlation with black-and-white recording; and future radar recordings for correlation with black-and-white and IR type recording |
| Total payload weight | - | 500 pounds |
| Dimensions | - | limited by vehicle space available |

STAT

From an optical point of view a lens diameter greater than three inches should give the desired ground resolution; and an 18-inch focal length is adequate when used to cover a slit where the film plane

may be curved to match the lens field, provided the field coverage is not too high. Since future improvements can be expected in the lens, film, and IMC properties, the initial design should be realistic for short term developments but should allow for inidividual elemental improvements as they become available.

With knowledge of almost all conditions, the following table of specifications seems entirely possible:

| | 2-yr Design | 1-yr Design |
|---|---|---|
| Exposure time | 1/150 sec. | 1/100 sec. |
| Lens diameter | 4½-inch | 3½-inch |
| Lens focus | 18-inch | 18-inch |
| Picture width (for each of 2 strips) | 110 mm | 110 mm |
| Ground coverage width (max. stereo coverage) | 25,000 ft | 25,000 ft |
| Ground coverage length | 8,300 miles | 8,300 miles |
| Ground resolution for lens-film combination | 2 feet | 3 feet |
| Film resolution requirement [illegible] contrast | 150 lines/mm | 110 lines/mm |
| Picture lines across film width | 13,750 | 8,000 |
| Scale | 66,000 | 66,000 |
| Length of film for above conditions | 670 feet | 670 feet |
| Film width (for 2 strips side by side) | 9½ inches | 9½ inches |
| Combined camera-film resolution | 125 lines/mm | 75 lines/mm |
| Lens f number | f/4 | f/5.6 |
| Lens resolving power over area | 200 lines/mm | 100 lines/mm |
| Film use rate per second (about) | 0.525 inch | 0.525 inch |
| Slit width | 0.004 - inch | 0.005 + inch |

The largest factors contributing to the loss of resolution in high-altitude reconnaissance pictures are: (1) failure to obtain and to use the correct IMC; (2) vibrations which result from shutters, film advance mechanisms, and other intermittently moving masses; (3) lens flare; (4) incorrect exposure; (5) use of mirrors, moving optics, or the like; (6) incorrect selection of most suitable films. By making maximum usage of the film and lens capabilities more emphasis can be given to IMC measuring devices and correction. This problem exists in all types of cameras, but its solution in a slit camera introduces fewer complexities. With the better resolution proposed here it may be necessary to deliver a higher order of accuracy than expected. The lateral slit camera minimizes all camera vibrations as well as permitting best reduction of lens flare.

It is the purpose here to recommend a slit type camera in which the slit is transverse to the direction of flight and is fixed relative to the lens and camera mounting. IMC and film are, therefore, one motion -- that is, counter to the direction of flight.

In its simplest form a single-slit, single-lens camera would photograph with very high resolution a two-dimensional picture. (See Figure I.) However, stereoscopic images are not readily obtained, although some optical manipulation could be used to place stereo pairs side by side on one or two films. The best solution probably lies in the use of two lenses photographing the same strip of territory,

recording the pictures side by side on $9\frac{1}{2}$-inch wide film. The two views, differing in time and, therefore, in position, would be suitable for stereoscopic viewing. This is shown in Figure II. The slits can be located conveniently along the length of the film; this convenience could include such factors as mechanical separation, ease of manufacture of viewing equipment, curvature of lens field, etc. Other variations of this same design would permit partial stereo coverage combined with additional two-dimensional fringe coverage as shown in Figure III, or double width coverage (10 miles) without stereo, as shown in Figure IV.

Other possibilities, such as one long lens for best detail accompanied by a short lens for large area coverage, could be used if two strips of film and different IMC and slit widths were provided. (See Figure V.) In another variation, by the use of di[illegible] emulsions or filters, one film could be used for one wavelength [illegible] such as the green region and the other in the far red region. O[illegible] side of the film might record the visible spectrum while the oth[illegible] used for IR or even a combination of IR and radar.

With basic usage of the scheme of Figure II and thus retaining stereoscopy, different exposures might be made with each lens, gaining thereby in shadow or highlight information. Another variable in usage is possible by making one lens slightly different in focal length than the other, giving slightly different scales. [illegible] would result in slightly different effective IMC which would help corr[illegible] for altitude or velocity errors.

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Up to this point in this presentation, consideration has been given mostly to obtaining sharp photographic images on the film. In addition, the provision of a more stable platform may be necessary as a result of the vehicle characteristics not known at present. Further, it may be of advantage to correct for large "yaw" angles as a part of the IMC system if these angles are large.

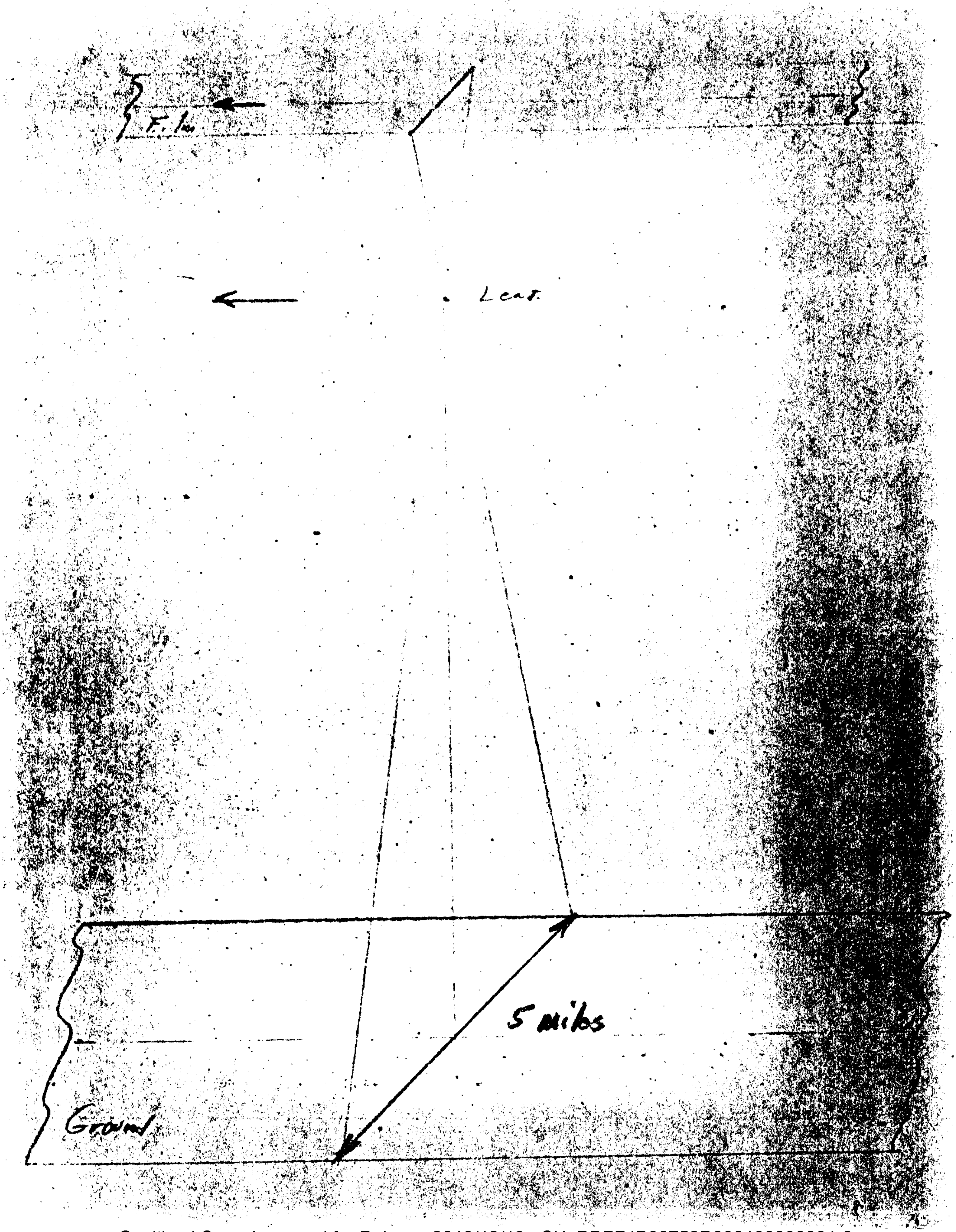
Uniform time signals and information to establish nadir would have to be photographed along the edges of the film to assist in measurements and coordination with other instrumentation. The inclusion of the elements of an inertial guidance system would be of considerable advantage for navigation, photogrammetry, nadir determ[illegible] angle of yaw measurement, etc.

With adequate guidance system and the use of check poi[illegible] [illegible] photographic recordings should be useful for photogrammetry [illegible] [illegible] for reconnaissance intelligence.

This part of the system is probably the same for any [illegible] [illegible] camera mechanism, and, therefore, only the recognition of the [illegible] [illegible] such problems is included here at this time.

It is understood that a number of viewing and printing devices already exist for the "two strip" stereo recording on film [illegible] recommended here. With the much higher resolution obtainable in to[illegible] camera systems it may be necessary to increase magnifications and [illegible] improve contact and enlarging printers to take full advantage of th[illegible] [illegible] negatives.

Because of the shortage of time in gathering the mater[illegible] for this presentation only the basic concepts could be described. It is hoped that a much fuller description can be made available in [illegible] near future if you express an interest in having us do further explor[illegible]


Film
Lens
5 miles
Ground

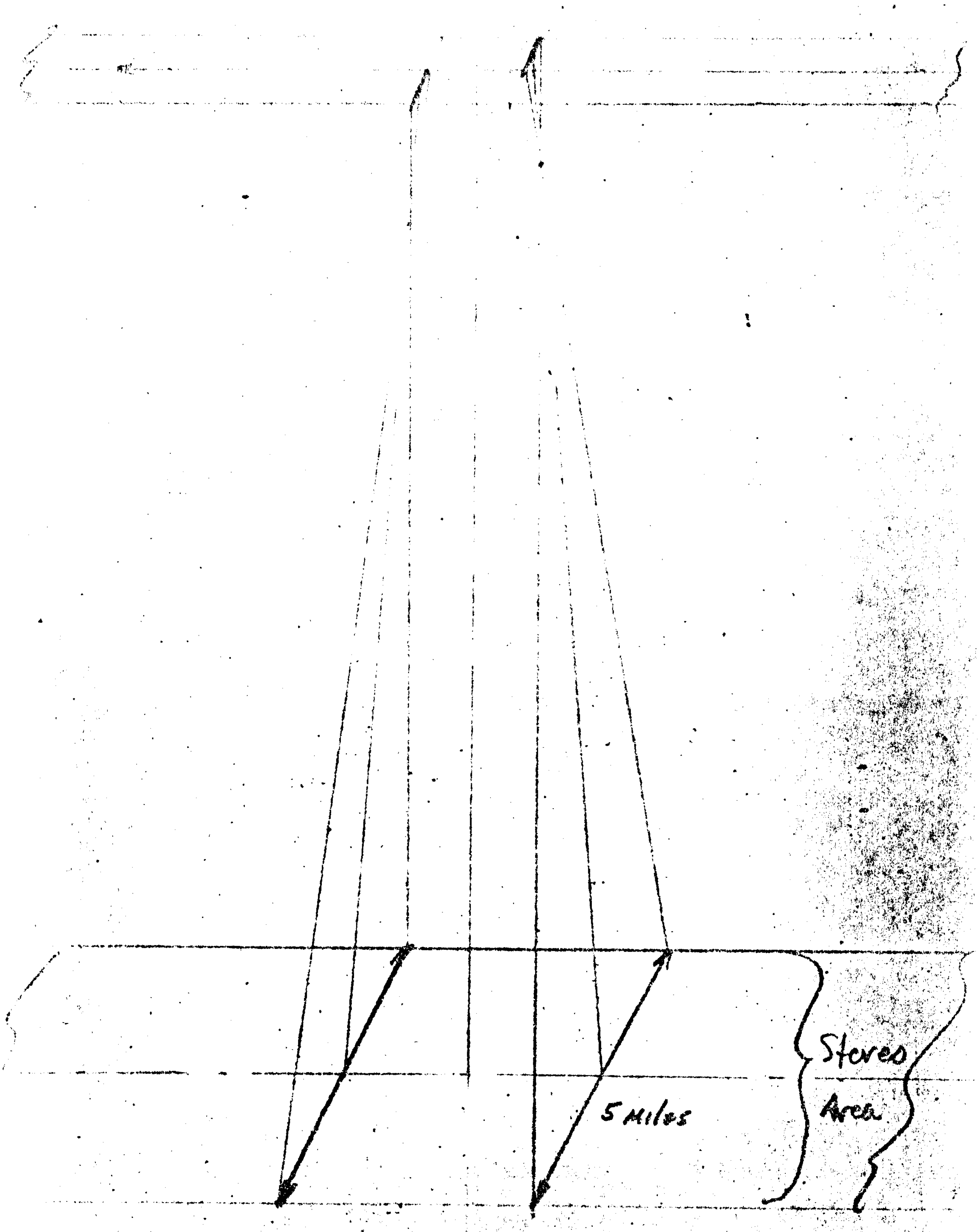



Fig II

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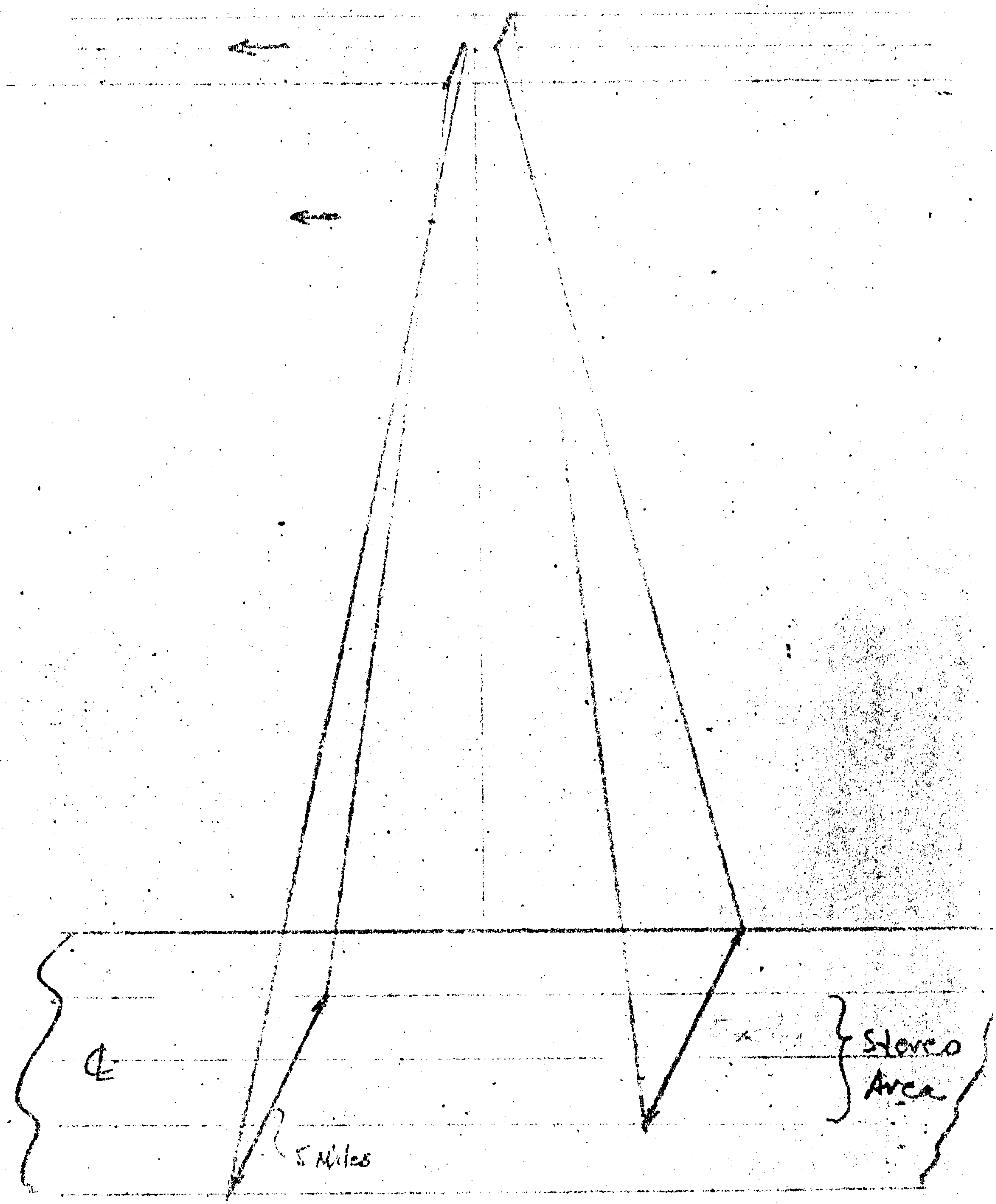



Fig III

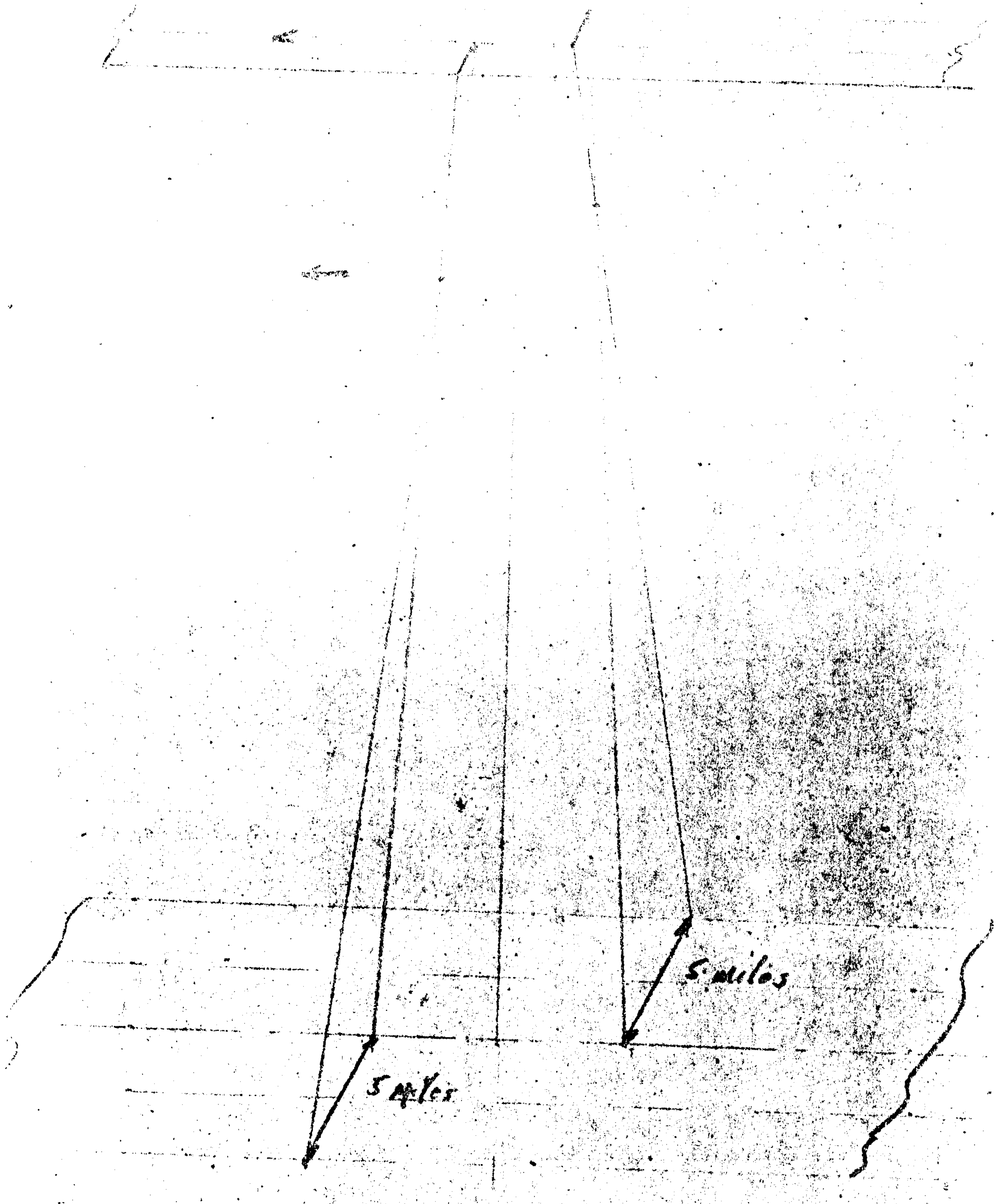
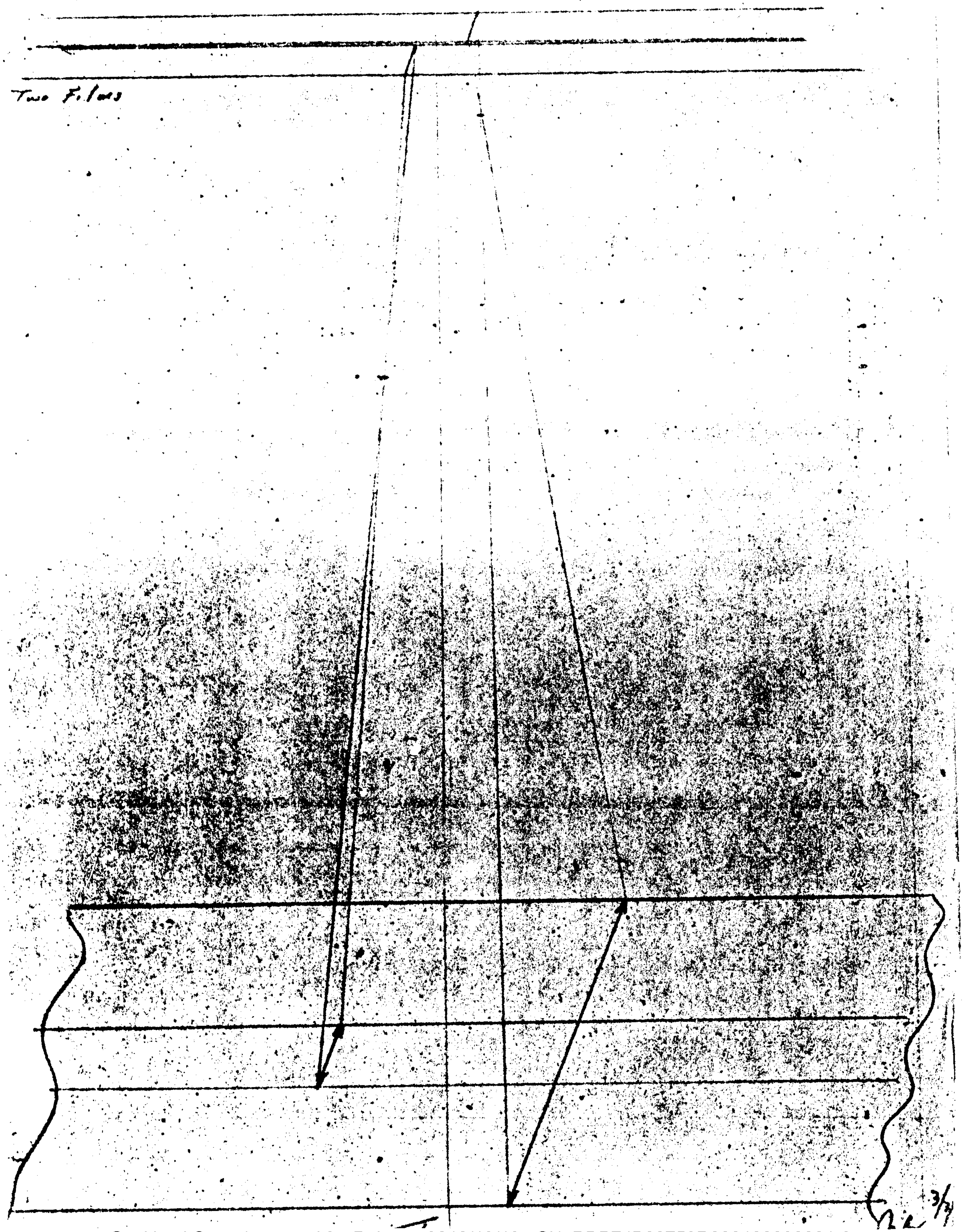



Fig IV

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